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THE EFFECTS OF LOW-ALTITUDE AIRCRAFT ON MOUNTAIN SHEEP HEART RATE AND BEHAVIOR

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The experiments reported herein were conducted according to the "Guide for the Care and Use of Laboratory Animals, "Institute of Laboratory Animal Resources, National Research Council.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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13. ABSTRACT *(Maximum 200 words)*

We determined the influence of F-16 aircraft overflights on mountain sheep (Ovis canadensis nelsoni). We created an enclosure and calibrated the area for sound created by F-16 aircraft flying along the ridgeline, approximately 125 m above ground level. In 1990 we placed 12 mountain sheep in a 320-ha enclosure in the Desert National Wildlife Refuge, Nevada. We monitored their behavior for 1 year to ensure they were habituated to the area before they were influenced by the F-16 aircraft. Habitat use and activity of mountain sheep in the enclosure was similar to habitat use and activity of free-ranging mountain sheep.

In May 1991 we instrumented 5 mountain sheep with heart-rate monitors and added them to the population. From May 1991 to May 1992 F-16 Aircraft flew over the enclosure during 3 1-month periods. We recorded heart rate and behavior of sheep 15 minutes prior to, during, and after overflights. Heart rate increased above normal in 21 of 149 overflights but returned to normal within 2 minutes. We conclude that when F-16 aircraft flew over the enclosure, the noise levels created did not alter behavior or increase heart rate to the detriment of the population.

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PREFACE

In 1988 the United States Air Force (USAF) decided that an understanding of the relationships between noise from low-altitude aircraft and wildlife was necessary. Increased demands on the use of lands under USAF airspace dictated that land managers understood if and how aircraft noise influenced wildlife. To that end we began a series of studies to document the influence of noise from low-altitude jet aircraft on habitat use, behavior, and heart rate of desert mule deer (*Odocoileus hemionus crooki*) and mountain sheep (*Ovis canadensis mexicana*).

The first study was conducted at the University of Arizona, Tucson, where we monitored the behavioral and physiological responses of sheep and deer to simulated aircraft noise. We applied technology and information from the first study to a population of mountain sheep in Nevada. We constructed a 3.2 km^2 enclosure and placed 12 mountain sheep inside. After they were habituated to the pen and habitat they were exposed to actual overflights by F-16 aircraft. This report presents our results.

Our intent is to provide data that are useful for land managers and the USAF so that both can make informed decisions. As more demands are being placed on wildlife and their habitats these are part of the data needed for management.

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1.0 INTRODUCTION

One role of the United States Air Force (USAF) is to train pilots for national defense. The rigorous demands placed on military tactical aircrews to maneuver high speed aircraft along carefully planned routes, taking advantage of terrain to avoid detection by defensive forces, requires frequent training to maintain proficiency (Holland 1991). Low-altitude military training flights (≤419 m above ground) are regulated by the Federal Aviation Administration and the Department of Defense. Two types of air space (i.e., special use and military training routes) are designated to minimize impacts with other air space users. Changing air space designation requires compliance with the National Environmental Policy Act guidelines. Most air space designations were made from 1950 to the 1960's (Holland 1991). More recently, public lands underlying the military designated air spaces have been set aside as national parks, wildlife refuges, or wilderness areas to be preserved for public enjoyment (Holland 1991). Some lands under USAF air space (i.e., national parks, refuges, wilderness areas) have been in question: should flying over them be restricted or eliminated?

Human encroachment and development has altered wildlife habitat on private and federal lands throughout the United States (Leslie and Douglas 1979, Etchberger et al. 1989). Recently, wildlife managers have expressed concern about the influence of aircraft noise on ungulate populations (Asherin and Gladwin 1988). For example, the General Accounting Office reported that overflights at the Cabeza Prieta National Wildlife Refuge (NWR), Arizona, may harm mountain sheep and Sonoran pronghorn antelope (Antilocapra americana sonoriensis). The Kofa NWR in western Arizona does not permit military overflights below 458 m (M. Haderlie, U.S. Fish and Wildl. Serv., pers. commun.; Gladwin et al. 1988) as a measure to protect mountain sheep and other wildlife.

Several studies examined the behavioral and physiological effects of aircraft noise on domestic animals (Bell 1971, Bond et al.

1974, Espmark et al. 1974, Ewbank 1977, Manci et al. 1988) and recent studies have examined the influence of subsonic aircraft on wildlife. However, there is conflicting evidence that aircraft noise has a negative influence on wild animals. Reindeer (Rangifer tarandus) exhibited strong panic responses to fixed-wing aircraft flying ≤152 m above ground level but did not respond as strongly to helicopters (Calef et al. 1976). Fixed-wing overflights (Cessna 172, 182 aircraft [Krausman and Hervert 1983]) ≥100 m above ground did not disturb mountain sheep in Arizona. However, Stockwell et al. (1991) studied mountain sheep in the Grand Canyon, Arizona and reported that in winter mountain sheep foraged less efficiently in the presence of helicopters than when helicopters were absent. In addition, Bleich et al. (1990) reported that mountain sheep moved 2-5 times farther the day following a helicopter survey than on the previous day and changed home-range polygons by 8-83 km following helicopter surveys. When aircraft (i.e., helicopters) fly close to the ground (≤100 m) they may create more disturbances than higher flying aircraft. Krausman et al. (1986) reported that desert mule deer (Odocoileus hemionus crooki) in south-central Arizona changed habitats in response to low-altitude aircraft (<100 m) but did not change habitats when aircraft flew >100 m above them.

Domestic animals and wildlife initially respond to aircraft noise with a startle reaction. Sporadic jumping, galloping, bellowing, and haphazard movement were a few responses of large farm animals observed by Cottereau (1978). Harrington and Veitch (1991) reported low jet overpasses "... indicated an initial startle response but otherwise brief overt reaction by woodland caribou (Rangifer tarandus) on late-winter alpine tundra habitats." These behavioral responses to noise have caused secondary injuries in domestic animals (e.g., broken legs [Cottereau 1978], and may cause stampedes in wild animals that could result in drowning and trampling (Sinclair 1979) or other forms of mortality (Harrington and Veitch 1991).

Animals react differently to sound intensity, duration (Ames and Arehart 1972, Borg 1981), and direction (Tyler 1991). Ames and Arehart (1972) investigated the effects of intermittent bursts of white noise, music, and miscellaneous sounds from 75 to 100 decibels (dB). Habituation to intermittent sounds was gradual and minimal in each of their experiments.

Recently Workman et al. (1992) examined various types of disturbance to ungulates from human activity including sonic and subsonic booms created by F-16 aircraft. Workman et al. (1992) reported that during their 5 week experimental period, pronghorn antelope, elk (Cervus elaphus), and mountain sheep were exposed to a combination "... of sonic booms by F-16 aircraft, subsonic flyovers by F-16's and low elevation flyovers by a single engine propeller driven Cessna 182 airplane ...", and UH-1 helicopter overflights. During their experiments aircraft created increases in the heart rates of animals but the increased heart rates decreased with repeated overflights. Workman et al. (1992) concluded that habituation to noise occurred and for mountain sheep "... there was evidence of habituation after repeated exposures."

Heart rates have been measured in wild animals because heart rate is a " ... sensitive indicator of arousal, the first stage of an alarm reaction to stress (MacArthur et al. 1982)" (Nilssen et al. 1984, Fancy and White 1986). Heart rate varies with sound level, intensity, duration, and probably frequency of auditory stimuli (Ames and Arehart 1972). Heart rate telemetry experiments have determined some forms of stimuli that intensify cardiac response and their relation to behavioral activities (Ames and Arehart 1972; MacArthur et al. 1979, 1982). Should some forms of arousal (e.g., aircraft overflights) be excessive, the added cost of excitement may interfere with health, growth, and reproductive fitness (Geist 1979:5).

Habituation to intermittent sounds ≥75 dB is gradual (Ewbank 1977, Espmark and Langvatn 1985). However, studies with rodents (Borg 1979), domestic sheep (Ames and Arehart 1972), elk (Espmark and Langvatn 1985, Workman et al. 1992), mountain sheep and pronghorn antelope (Krausman et al. 1992, Workman et al. 1992) and desert mule deer (Krausman et al. 1992) have shown that animals can become habituated to noise.

The effects of noise from low-altitude subsonic aircraft on animals have not been studied often or extensively. Espmark et al. (1974) reported that domestic animals responded more intensely to low-altitude aircraft noise than to sonic booms. Previous studies that have examined the influence of noise on wildlife rarely describe the noise stimulus.

Military overflights concern land managers (e.g., U.S. Fish and Wildl. Serv., Nev. Dep. Wildl.) because the unknown effects of auditory and visual stimuli are a potential threat to wildlife populations. How animals respond to aircraft noise may be important in management decisions about USAF use of air space and wildlife subjected to overflights.

In response to the need for more information about the effects of overflights on wildlife, Krausman et al. (1992) examined how captive mountain sheep and desert mule deer responded to noise created by military aircraft. Our objectives in this study are to describe how mountain sheep respond to measured and controlled noises created by F-16 aircraft overflights. We used mountain sheep because they inhabit areas subjected to military overflights and are sensitive to human intrusion into their habitat (Etchberger et al. 1989). We document the changes in heart rates and behavioral responses to examine 2 questions. Does low-altitude aircraft noise alter the behavior of mountain sheep, and does low-altitude aircraft noise create a chronic increase in heart rate? Chronic increases in heart rate would

alert managers that low-flying jet aircraft are detrimental to mountain sheep (Geist 1979:5, MacArthur et al. 1979, Fancy and White 1986).

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2.0 STUDY AREA

To examine the influence of low-flying jet aircraft on the behavior and heart rate of mountain sheep we needed to select a study site that had specific criteria.

1. The area needed mountain sheep habitat.
2. The area had to be administered by an agency that would allow an enclosure to be constructed on their land.
3. The area needed to be isolated from human activity as much as possible.
4. Mountain sheep populations needed to be close to or on the study area.
5. The area had to be near a military installation with fighter aircraft that would be willing to fly over the study area at designated times.
6. Sheep placed in the enclosure should not have previously been exposed to low-flying jet aircraft.

After considering several potential sites in Arizona, Utah, and New Mexico we selected a study site at the north end of the Desert National Wildlife Refuge (DNWR). The DNWR had an array of habitat for mountain sheep on surrounding ranges and was administered by the USFWS with close cooperation with the Nevada Department of Wildlife (NDW). Both agencies were interested in translocating mountain sheep from other parts of the DNWR to the north. The animals we used would be released upon completion of the study to potentially establish a herd in the area. The selected site was also >5 km from public roads, not well known and, to our knowledge, was only visited by 1 hunter during the entire study. Mountain sheep occasionally used the site and adjacent ranges supported populations. Nellis Air Force Base was approximately 150 km south of the site and the USAF agreed to provide aircraft overflights in conjunction with regularly scheduled training. In addition, the site was under restricted airspace and overflights had been minimal.

The study area was in the northeast corner of the DNWR, 150 km north of Las Vegas, Nevada. The DNWR was established in 1936 for the preservation of mountain sheep. It was 6,000 km^2 and included 6 mountain ranges varying in elevation from 625 to 3,724 m. Land use on the refuge included livestock grazing until 1966. The western half of the DNWR has been used as a bombing and gunnery range by the Department of Defense since 1940 (Burger 1985).

We constructed a 3.2 km^2 enclosure north of the Sheep Range (Fig. 1), an area noted for abundant water availability (Burger 1985). The Sheep Range, and the neighboring Las Vegas and Desert Ranges, made up the largest block of habitat for desert races of mountain sheep in Nevada, and supported the largest population of this race in the United States (Burger 1985). Nevada's population of mountain sheep increased from 1977 to 1987, to approximately 4,600 individuals (Delaney 1988).

Climatic data was recorded 10 km east of the enclosure at Pahranagat National Wildlife Refuge. The average daily high/low temperatures for the summer (Jun-Aug), fall (Sep-Nov), winter (Dec-Feb), and spring (Mar-May) were 36/17, 26/6, 13/-4, 21/4 C, respectively. These temperatures were similar to averages from 1965 to 1987. Approximately 33% of annual rainfall (12.55 cm) fell in both winter and summer, and 17% fell in both fall and spring. This was 24% lower than the average annual precipitation (16.5 cm) from 1965 to 1987, and was representative of the drought occurring throughout the western states since the mid-1980's.

The 3.2 km^2 enclosure (Fig. 2) was bounded by a 2.4-m high fence (1.5 m of net wire and 3 strands of barbed wire spaced 0.3 m apart) (Fig. 3). The encompassed portion of the mountain was in a north-south direction, and was characterized by steep, precipitous slopes on the south and northeast end, and relatively

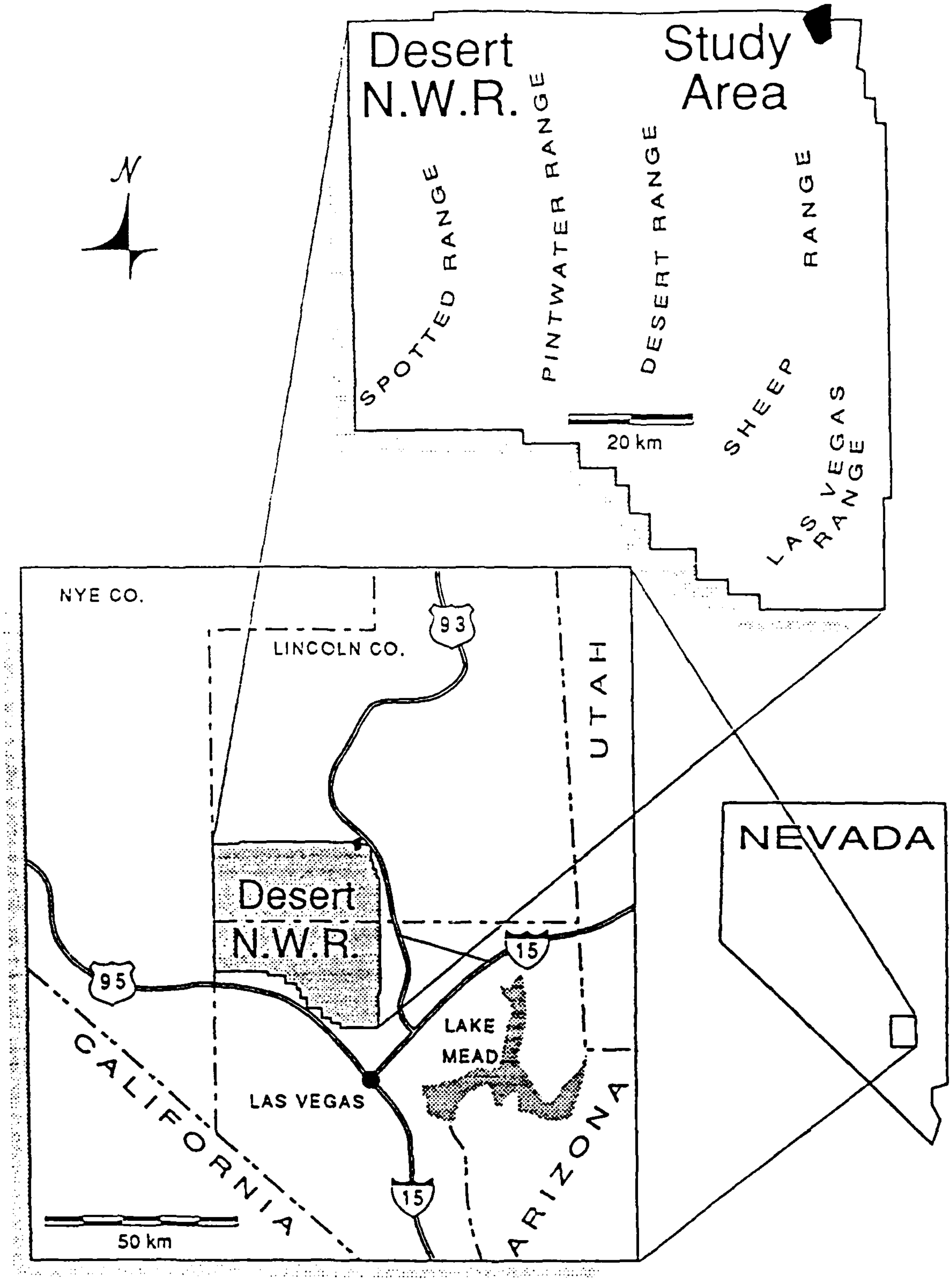

Figure 1. Location of the Mountain Sheep Enclosure (Black Polygon), Desert National Wildlife Refuge, Nevada, 1990-1992.

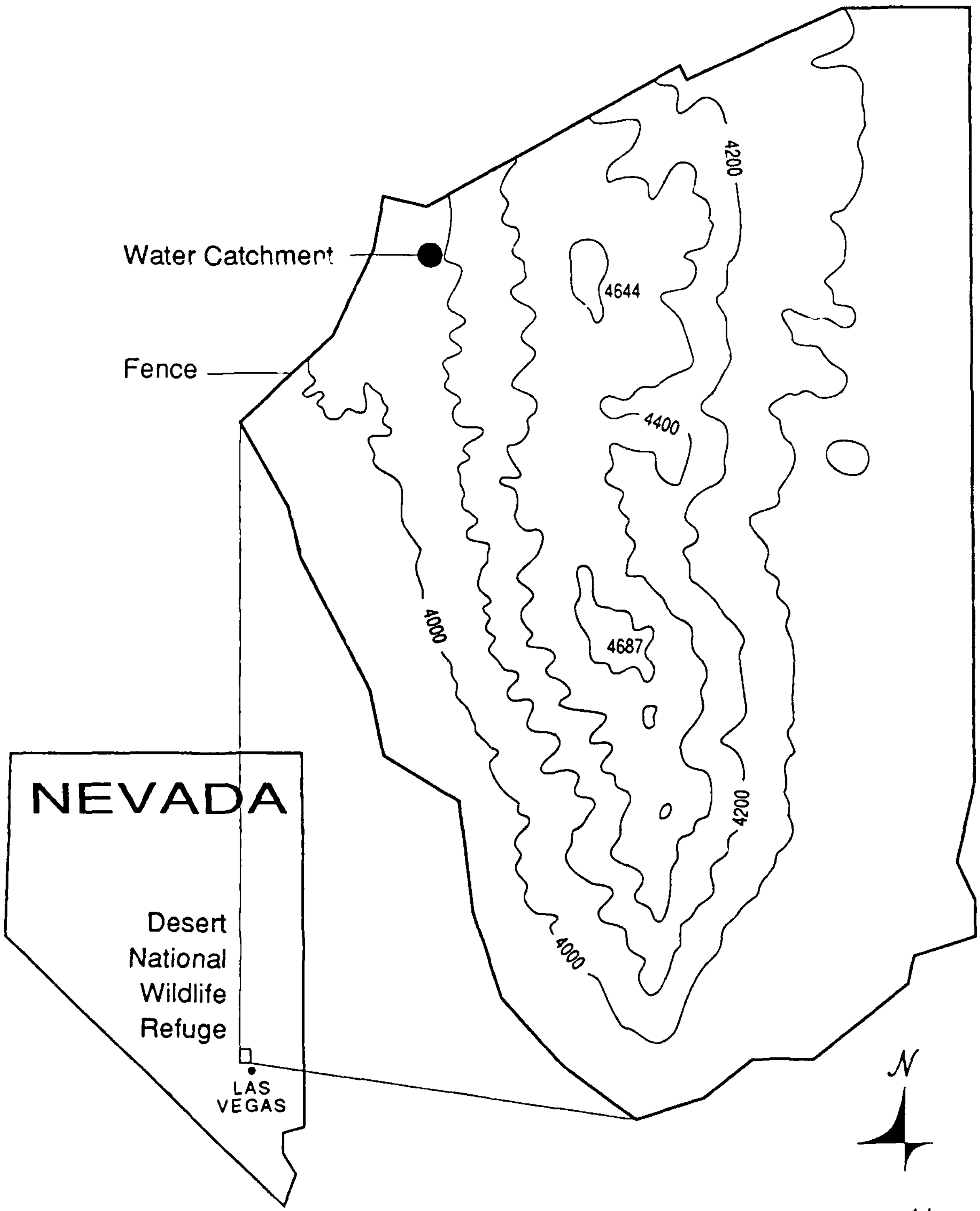

Figure 2. Location of the 320-ha Mountain Sheep Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1992.

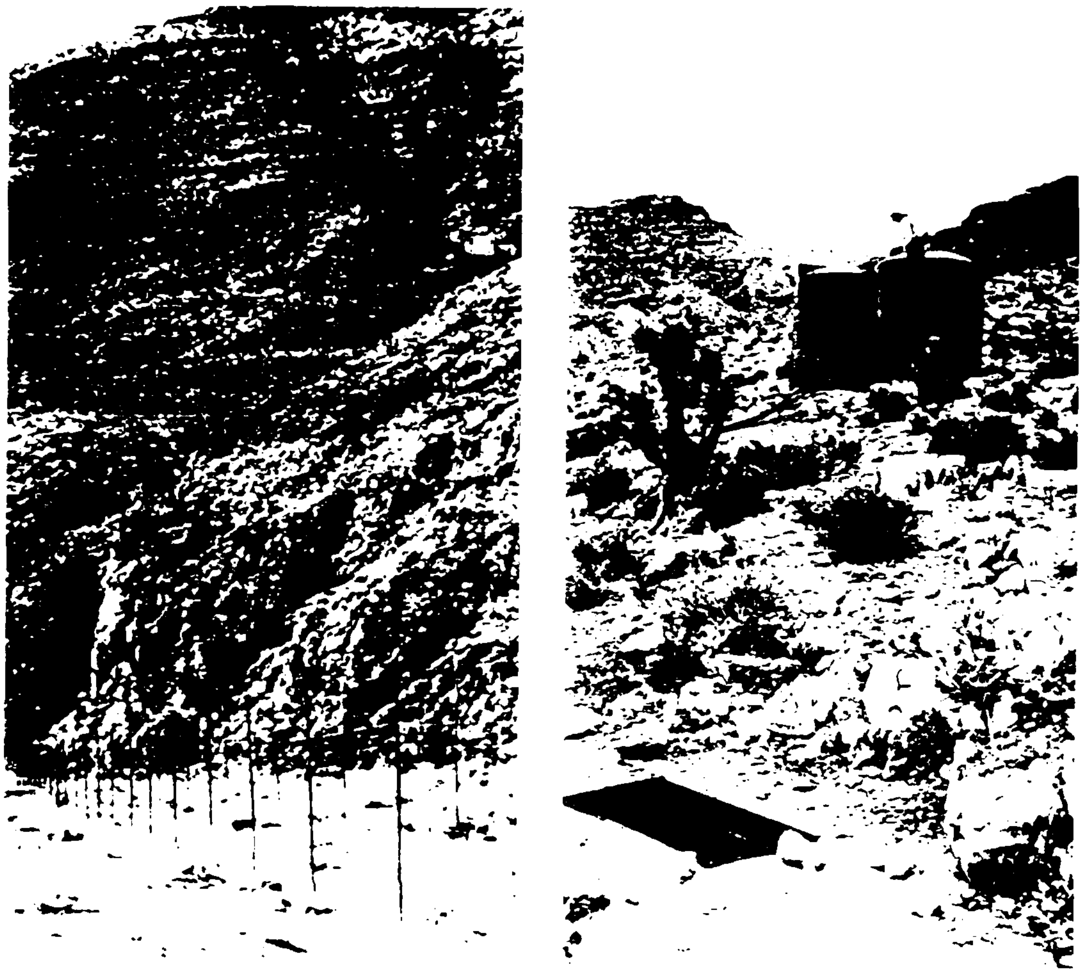

Figure 3. Fence and Water Catchment in a 320-ha Mountain Sheep Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1992.

moderate slopes on the northwest. Deep drainages were on the southern half and east side of the mountain. There was a long, relatively flat portion of the enclosure on the east side, running the length of the mountain and approximately 200 m wide from fence to bajada (the topographic area between midslopes and the flats, $\leq 25^{\circ}$). The west side fence extended closer to the mountain, thus, only rolling bajada was in the northwest corner. Elevations ranged from 1,267 m in the wash along the west fence, to 1,562 m at the highest point. The enclosure was entirely within the desert scrub vegetation association described by Bradley (1964).

The enclosed portion of a mountain included most of the habitats available to mountain sheep in the DNWR with the exception of the pinyon pine (*Pinus monophylla*)/Utah juniper (*Juniperus osteosperma*) association (Burger 1985). Our study, therefore, examined use of habitats within the enclosure with respect to their availability. We were aware that habitats within the enclosure did not include all of the habitats available to free-ranging mountain sheep in the surrounding ranges.

3.0 METHODS

This study was conducted from May 1990 to May 1992 and was divided into 2 parts. From May 1990 to May 1991 mountain sheep were placed in the enclosure for habituation. They became habituated and familiar with the area prior to the second part of the study that included the treatment (i.e., overflights).

3.1 NOISE CALIBRATION

After the enclosure was completed and before sheep were placed inside, a calibration was conducted of the sound field produced by experimental overflights. Calibration allowed us to determine noise generated throughout the area from F-16 aircraft 125 m above ground level, flying with 90% power settings and a flight course ± 63 m of the prescribed flight path. We documented noise levels from F-16 and A-10 aircraft but selected the former for experimention. The F-16 generates more noise than A-10 aircraft (Appendix A), is a common USAF aircraft that flies over mountain sheep habitat, and is available from Nellis AFB. From December 1989 through January 1990 noise calibrations occurred at the study site following procedures described by R. E. Nugent and D. S. Barber of Acentech Incorporated (Site noise calibration for the desert bighorn sheep study, Acentech Inc., Rep. 38, 15+pp., 1990) (Appendix A).

3.2 CAPTURE AND MARKING

We captured 14 mountain sheep on 1 and 2 May 1990 (5M, 9F); 1 male and 1 female died. We located sheep with a Bell Jet Ranger helicopter and subsequently captured them with a net gun (Krausman et al. 1985a). Animals were captured from Desperation to Lamb canyon in the north end of the Sheep Range, DNWR, by personnel from the Nevada Department of Wildlife, U.S. Fish and Wildlife Service, and the University of Arizona. Sheep were captured, blindfolded, hobbled, and transported by helicopter and horse trailer to the enclosure 50-60 km north of the capture sites. The population in the enclosure consisted of 1 yearling

female, 7 adult females, 1 yearling male, and 3 adult males (Table 1). One of the females was instrumented with an internal heart rate monitor following techniques modified from Bunch et al. (1989).

We radio-collared 10 sheep with 5 differently colored, mortality sensitive (model HP) collars (Telonics, Inc., Mesa, Ariz.) to assist in the location and identification of individual sheep. The 2 sheep without collars were females that were physically distinguishable. We color coded the collars so that the individuals with the same color were of opposite sex. The exception to this were 2 females sharing red collars; these sheep were also physically distinct from each other.

3.3 HABITAT

We visually delineated habitat associations in the enclosure. We calculated relative availability of vegetation associations with a non-mapping technique (Marcum and Loftsgaarden 1980) using 525 random points plotted on a 7.5 minute topographic map of the study area (Thompson 1987). Every random point was assigned to 1 of the 9 vegetation associations, and the number of points in each area was summed to calculate relative availability of each association. Relative availability of slope was determined using the same non-mapping technique with 525 random points (Marcum and Loftsgaarden 1980, Thompson 1987). Botanical nomenclature followed Kearney and Peebles (1951).

Composition of vegetation associations was quantified using the line intercept method (Canfield 1941). We randomly placed 16 30-m line intercept transects in each association during summer and winter. We recorded the width of each measured plant and the length of vegetation intercepting the transect to calculate relative percent cover for plant species in each vegetation association (Canfield 1941). Vegetation offering thermal cover (any structure or vegetation ≥1 m high beneath which standing or

Table 1. Mountain Sheep in a 320-ha Enclosure in the Desert National Wildlife Refuge, Nevada, May 1990 - May 1992.

Date	Age[a]	Sex[b]	Collar color	Collar frequency	Captivity born lambs[c]
5/1/90	3	M	Yellow	164.670	
	Ad	F	Yellow	164.670	3/30/91
	2	M	White	164.550	
	1	F	White	164.540	3/25/91
	1	M	Blue	164.950	
	Ad	F	Blue	164.391	4/02/91
	3	M	Orange	165.540	
	Ad	F	Orange	165.430	4/02/91
	Ad	F	Red	165.010[d]	3/25/91
	Ad	F	Red	165.411	
	Ad	F	None	(F #1)	
	Ad	F	None	(F #2)	3/25/91
5/2/91	Ad	F		164.570[d]	
	Ad	F		165.010[d]	
	Ad	F		164.322[d]	
	Ad	F		died[d]	
	Ad	M		164.270[d]	

[a] Ad = ≥ 2 yrs

[b] M = male, F = female

[c] Seven additional lambs were born in spring 1992.

[d] Individual implanted with heart rate transmitter.

bedded mountain sheep could seek shelter from direct sunlight [Gionfriddo and Krausman 1986]) for mountain sheep was recorded for all transects.

We collected habitat use data using modified instantaneous scan sampling, observing 1 animal at a time (Altmann 1974, Martin and Bateson 1986). We monitored locations and movements of individuals on a 7.5 minute topographic map, and collected activity data by observing each group member in turn and noting the first activity that occupied that individual for 10 continuous seconds (Krausman et al. 1989). We monitored bedding, foraging, standing, moving, social interactions, horning vegetation, drinking, and nursing by lambs. Location and activity observations began 1 June 1990, 4 weeks after release.

We quantified habitat use patterns of mountain sheep by season for 4 sex and age classes; adult males, adult females, juvenile males, and juvenile females. We used locations of individuals to determine relative use by the 4 age and sex classes of each vegetation association in the enclosure. We used Chi-square statistics to test the hypotheses that vegetation associations and slope classes were used in proportion to availability (Neu et al. 1974, Byers et al. 1984). If the null hypothesis was rejected ($\underline{P} < 0.05$), Bonferroni simultaneous confidence intervals were employed to construct a 90% confidence interval for proportions of time spent in each association by sex and age class (Zar 1984, Byers et al. 1984). If the percent occurrence of each vegetation association fell outside of the corresponding confidence interval, then we considered use different from availability. Treatments of data for use of slope were the same as those for use of vegetation associations.

3.4 BEHAVIOR

From May 1990 to June 1991 we collected data daily on the enclosed population of sheep. We used modified instantaneous

scan sampling with 10 minute sampling intervals (Altmann 1974, Martin and Bateson 1986), and recorded the first behavior that lasted 10 consecutive seconds as foraging, bedding (plus noting whether the individual was in the shade), standing without foraging, moving without foraging, or social (i.e., interacting with another individual). We first recorded the behavior of the animal located with radio-telemetry, and then the behavior of all other members of the group. The sequence of observation of group members was randomly ordered before the first scan. The individuals located with radio-telemetry were randomly selected without replacement until every member of the group had been selected. We recorded the location of all individuals at the first scan of each observation period using universal transverse mercator (UTM) grids. If an individual was foraging, the vegetation consumed was recorded as browse (woody perennials), forb (herbaceous perennials and annuals), grass, other (primarily succulents), or unknown. We made observations in bouts of ≤4 hours, with ≥4 hours between each observation period.

3.5 FORAGE

We used line transects to assess the availability of the vegetation classes (i.e., browse, forb, grass, unknown) at the site of the first foraging scan in a foraging bout (Canfield 1941). We used the UTM coordinates to record the location of the first foraging scan, and we mapped specific physical features of the site to facilitate relocation. We returned to the foraging site within 48 hours and assessed the total crown area of each class (Gysel and Lyon 1980), provided that we were able to identify the vegetation class consumed in ≥50% of the forage scans in a foraging bout. Foraging bouts were recorded as independent as long as the individual exhibited behaviors other than foraging, and/or was out of sight for ≥2 consecutive scans, and the distance between the location of the initial forage scan in a foraging bout was ≥30 m (the length of the transect). We

determined the direction of the transect from a random numbers table.

We compared the availability of browse, forbs, and grasses at the foraging site to their use with Chi-square analysis and Bonferroni simultaneous confidence intervals at the 0.05 level of significance (Byers et al. 1984). We used Mann-Whitney U-tests (2-tailed, 0.05 level of significance) to compare forage class use by dominant and subordinate groups within seasons, and to compare the availability of forage classes at the foraging site. We used Kruskall-Wallis one-way analysis of variance (ANOVA) tests to examine forage use between seasons for both groups, and forage availability between season. We did not include summer vegetation availability data because of small sample size.

3.6 ACTIVITY

The activity budgets were derived from modified instantaneous scan sampling (Altmann 1974, Martin and Bateson 1986). We transformed the percent data using the square-root arcsine transformation for the use of parametric statistics (Hass 1991, Zar 1974). We used one-way ANOVA tests to examine dominant and subordinate activity between seasons and to compare activity between hierarchy levels within each season. We used linear regression to examine differences in activity with respect to group size.

From May 1990 to May 1991 we documented habitat use and behavior of animals in the enclosure. During this time the sheep became habituated to the enclosure and we obtained baseline information that could be compared to the treatment period. During the baseline period we discovered that the heart rate monitor in the female sheep was functional and her heart rate could be received from up to 1 km. It also lasted >1 year, so during the treatment phase we captured 5 more sheep (4F, 1M) from the same areas the other penned animals came from. Each was instrumented with heart

rate monitors and added to the population. One of the females died after being in the enclosure 1 week. At the beginning of the treatment period 22 sheep were in the enclosure: the original 12 plus 6 lambs they produced and the 4 added animals (Table 1). Five sheep had heart rate monitors: a female from the beginning of the study, plus 3 added females and one added male.

3.7 OVERFLIGHTS

During the treatment we scheduled F-16 aircraft from the 57th FWW of Nellis Air Force Base, Nevada, to fly over the study area in 3 periods: 24 May-27 July, 1991; 20 September-20 November, 1991; and 4 February-2 April, 1992. Aircraft were randomly scheduled to fly over the study area during diurnal hours in the middle 4 weeks of each period. During the first week 1 aircraft/day was scheduled to fly over the area. The following 14 days ≤7 aircraft/day flew over the enclosure followed by 1 aircraft/day during the last week (Appendix B). Aircraft were not scheduled to fly on weekends.

Two biologists recorded data on individual sheep during overflights. We located sheep that had heart rate monitors and recorded their behavior, heart rate, and locations 15 minutes prior to, during, and 15 minutes after overflights. When possible we contrasted habitat use, behavior, and heart rate of sheep we observed prior to, during, and after overflights.

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4.0 RESULTS

4.1 HABITAT EVALUATION

We described 9 vegetation associations using 3 dominant plant species as indicators for each vegetation association (Table 2). Dominant plant species had the highest percent cover in each vegetation association. There was no season effect of relative frequency or percent cover of grass or shrub species ($P > 0.05$, Table 3).

Terrain providing escape cover (>60% slope) was limited to 22.1% of the enclosure. Thermal cover provided by vegetation structure was available under joshua trees (Yucca brevifolia) on west (22.1% cover) and east bajadas (11.0% cover).

4.2 USE OF VEGETATION ASSOCIATIONS

In general, mountain sheep use of the 9 vegetation associations was not in proportion to availability. The blackbrush (Coleogyne ramosissima) association, the main wash, east side bajadas, and east side draw associations were used less than expected. All other associations were used in equal or greater proportion than expected based on availability during ≥1 season by ≥1 sex or age class. All sex and age classes used the west aspect of the ridge more than the east aspect during all seasons ($P < 0.0001$).

4.2.1 Summer

Habitat use in summer was concentrated on the west side of the enclosure (98.2%) (Fig. 4). The yearling female used the west bajadas in proportion to their availability. Adult males used west draws in proportion to their availability. Bajadas, midslopes, and draws on the west side were used significantly more than expected based on availability by all other sex and age classes ($P < 0.05$). The ridgetop was used less than available by adult males, adult females, and the yearling female, but was used more than expected by the yearling male. He was observed standing on top of the ridge several times for extended periods.

Table 2. Species Indicators for 9 Vegetation Associations in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1992.

Vegetation association	Availability (%)	Indicator species	Common name
Main	2.1	_Larrea tridentada_	Creosote bush
wash		_Ambrosia eriocentra_	Wooly bursage
		Ephedra nevadensis	Mormon tea
West	9.2	_Yucca brevifolia_	Joshua tree
bajada		_Atriplex confertifolia_	Shadscale
		Ephedra nevadensis	Mormon tea
East	27.7	_Coleogyne ramosissima_	Blackbrush
bajada		_Larrea tridentada_	Creosote bush
		Mendora spinescens	Spiny menodora
West	15.5	_Atriplex confertifolia_	Shadscale
midslope		_Ephedra nevadensis_	Mormon tea
		Stipa speciosa	Desert needlegrass
East	18.4	_Atriples confertifolia_	Shadscale
midslope		_Ephedra nevadensis_	Mormon tea
		Hilaria rigida	Big galleta
West	9.2	_Artemesia bigelovii_	Flat sage
draws		_Ephedra nevadensis_	Mormon tea
		Muhlenbergia porteri	Bush muhly
East	9.5	_Fallugia paradoxa_	Apache plume
draws		_Atriplex confertifolia_	Shadscale
		Coleogyne ramosissima	Blackbrush

Table 2. Continued.

Vegetation association	Availability (%)	Indicator species	Common name
Ridgetop	2.1	Fallugia paradoxa	Apache plume
		Artemesia bigelovii	Flat sage
		Ephedra nevadensis	Mormon tea
Blackbrush	5.7	Coleogyne ramosissima	Blackbrush
		Yucca brevifolia	Joshua tree
		Larrea tridentata	Creosote bush

Table 3. Relative Availability and Percent Cover of Forage Classes Present for 9 Vegetation Associations in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1992.

Vegetation association	Relative availability	% cover of forage classes			
		Shrubs	Grasses	Forbs	Succulents
Ridgetop	0.021	82.94	9.89	4.22	2.94
Blackbrush	0.057	76.78	1.38	t[a]	21.79
Main wash	0.027	98.41	t	t	1.28
West bajada	0.092	74.60	2.95	t	22.14
East bajada	0.277	83.84	2.39	2.76	11.01
West midslope	0.155	80.96	11.63	3.56	3.85
East midslope	0.184	75.41	15.59	2.06	6.04
West draws	0.092	66.29	26.28	4.29	3.14
East draws	0.095	82.80	14.26	1.78	1.17

[a] t = <1%.

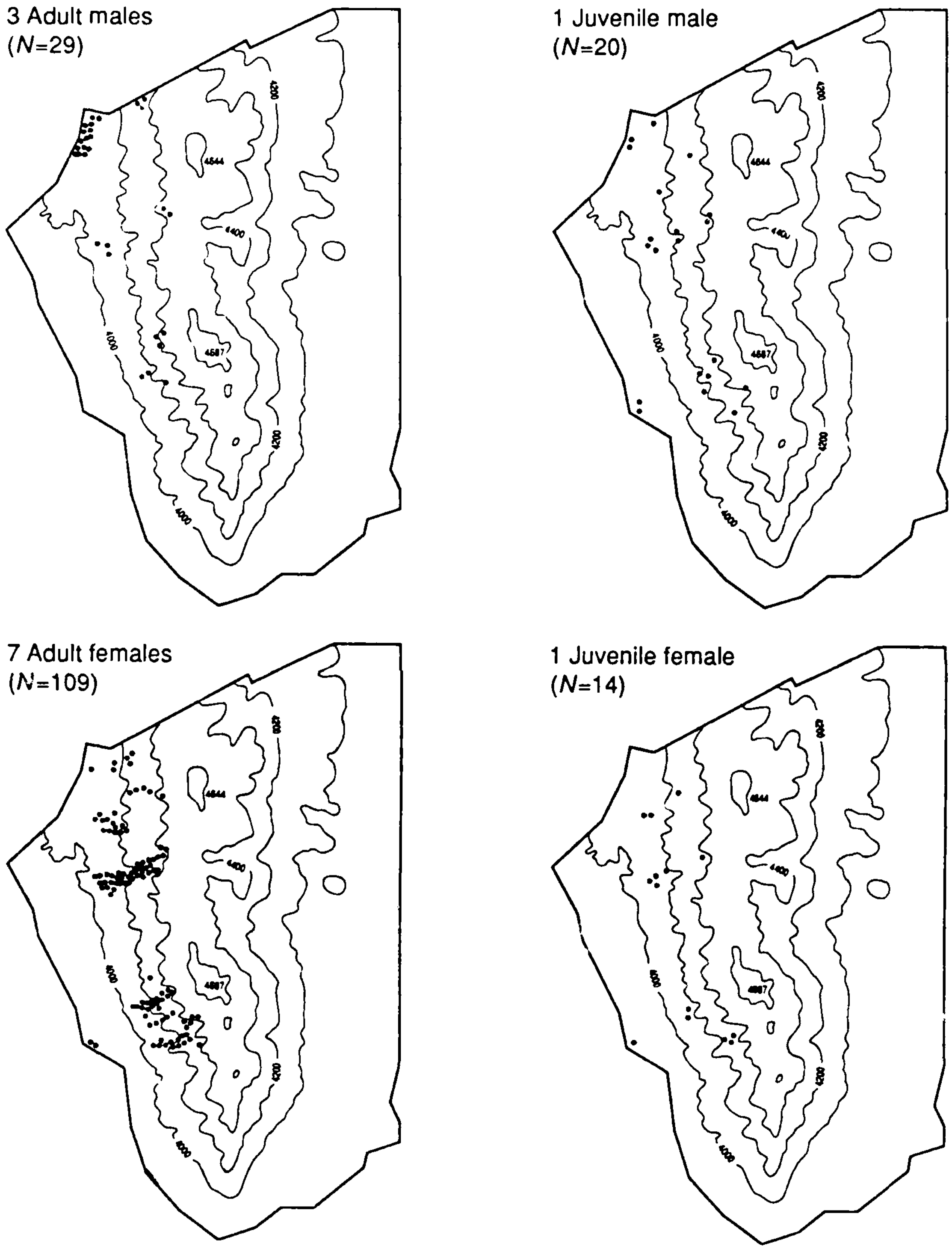

Figure 4. Summer (Jun-Aug) Distribution of Mountain Sheep (4 Sex and Age Classes) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991 ($\underline{N}$ = No. Locations).

Midslopes on the east side of the study area were used less than expected by all age and sex classes.

4.2.2 Fall

Habitat use in fall were concentrated on the west side of the enclosure (93.1%) (Fig. 5). Draws and midslope areas on the west side of the study area were used more than expected based on availability by all sex and age classes, and bajadas on the west side were used more than expected by adult males, the yearling male, and adult females. The yearling female used west bajadas equal to availability. The ridgetop was used more than expected by all age and sex classes.

4.2.3 Winter

Habitat use in winter was concentrated on the west side (87.9%) (Fig. 6). Draw areas on the west side were used less than expected by all age and sex classes except adult females, who used draws more than expected. Bajadas on the west side were used more than expected by adult males and the yearling ram, in proportion to availability by the yearling female, and less than expected by adult females. Of the 4 west side vegetation associations, midslope areas were used more (65.9%) by all sex and age groups. The ridgetop was used in proportion to availability by the yearling ram, and used less than expected for all other sex and age groups.

4.2.4 Spring

Habitat use in spring was more evenly distributed than in other seasons, with 57.0% of all locations occurring in the 3 west side vegetation associations (Fig. 7). West side bajadas were used more than expected by males, and less than expected by females. Draws and midslope associations on the west side were used more than expected by all age and sex classes. The ridgetop was used more than expected by adult males, adult females, and the

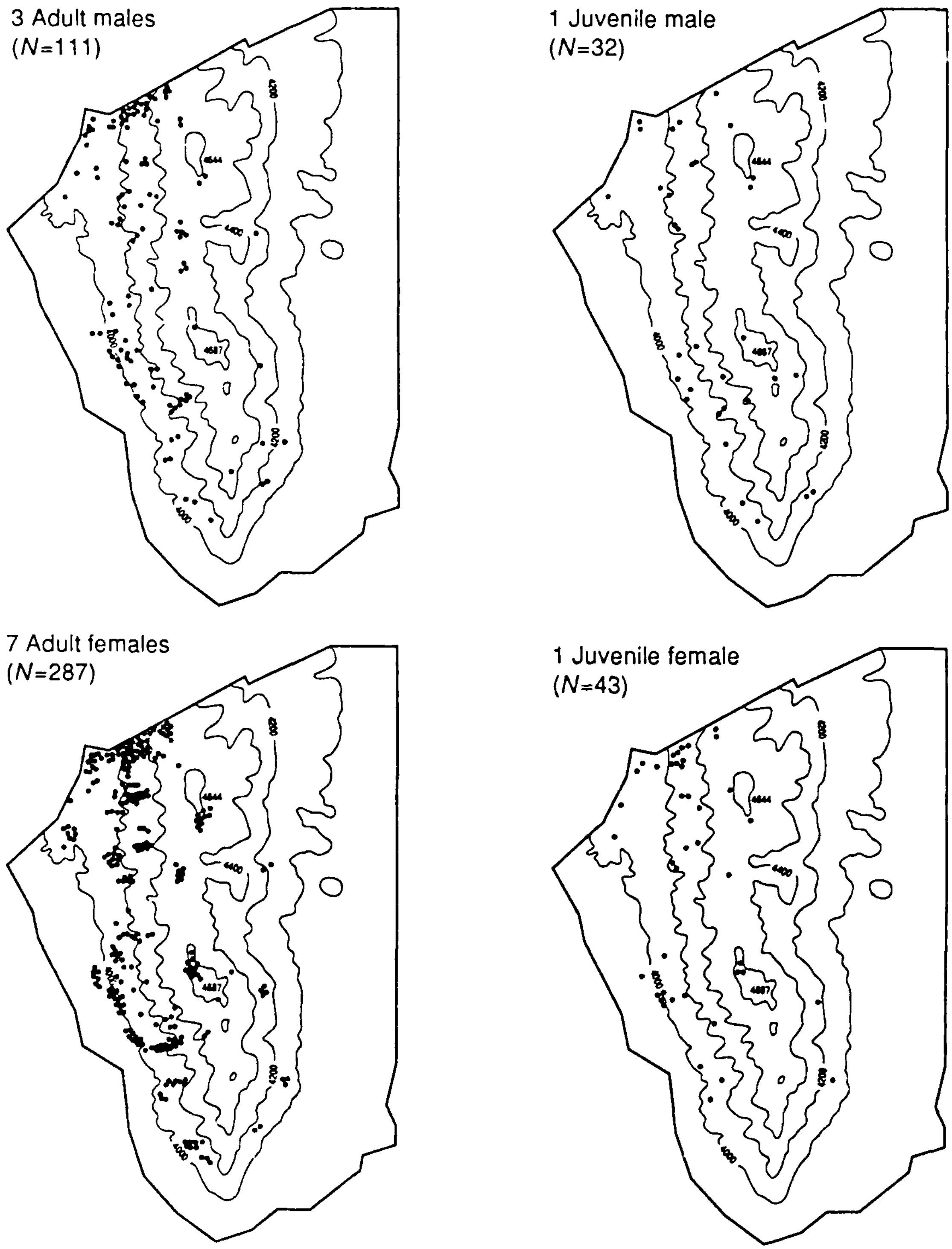

Figure 5. Fall (Sep-Nov) Distribution of Mountain Sheep (4 Sex and Age Classes) in a 320-ha Enclosure, Desert National.Wildlife Refuge, Nevada, 1990-1991 (N = No. locations).

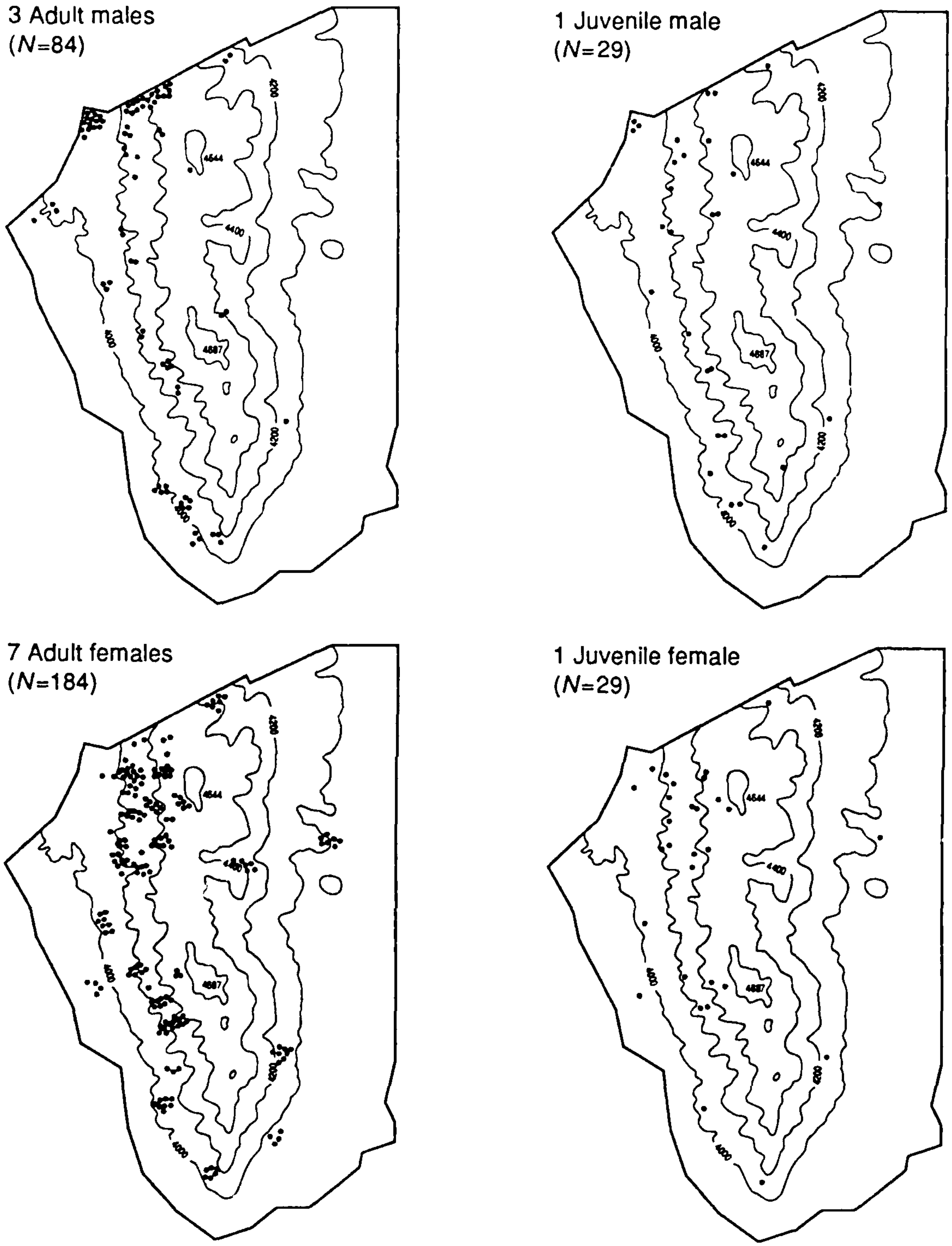

Figure 6. Winter (Dec-Feb) Distribution of Mountain Sheep (4 Sex and Age Classes) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991 ($\underline{N}$ = No. Locations).

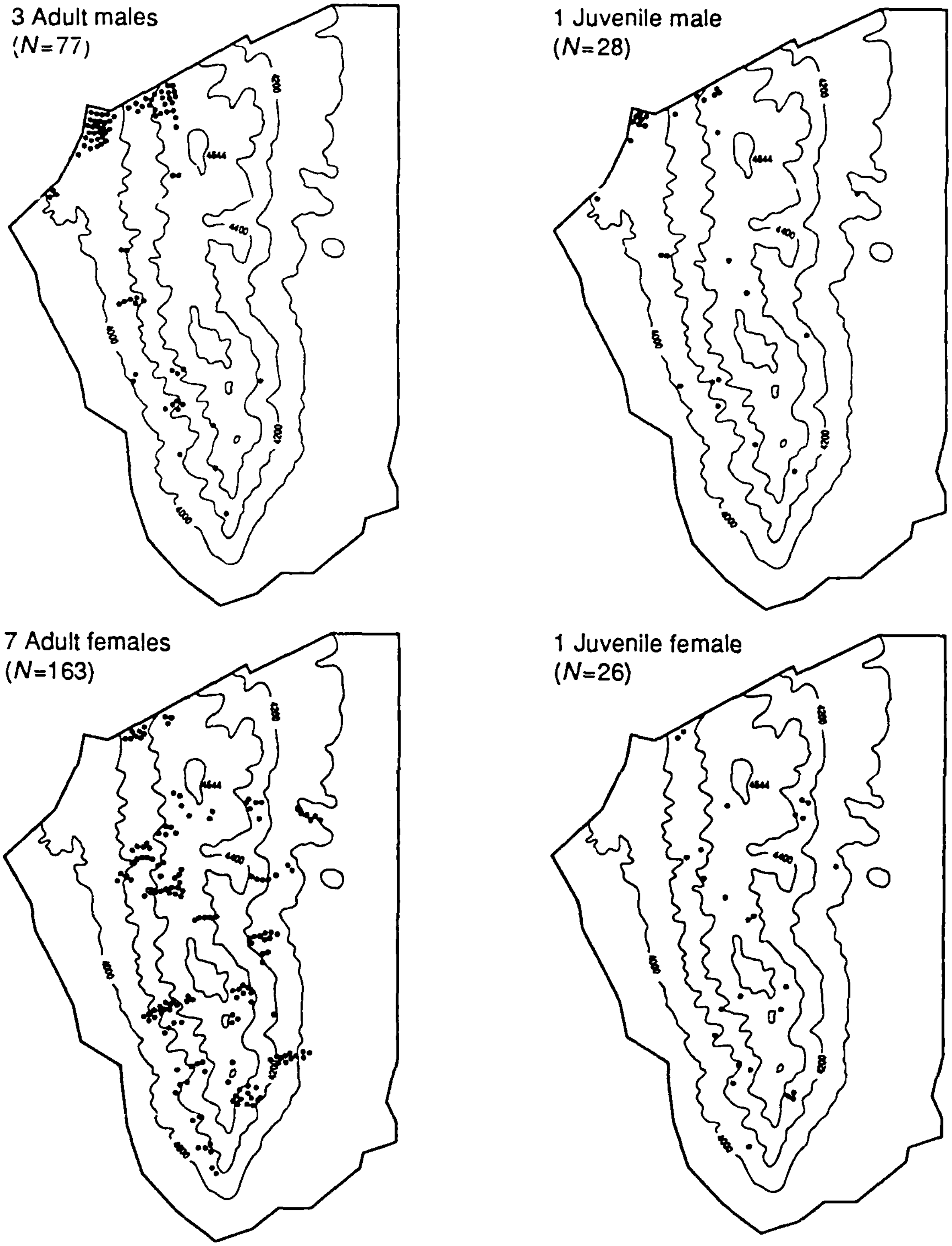

Figure 7. Spring (Mar-May) Distribution of Mountain Sheep (4 Sex and Age Classes) in a 320-ha Enclosure, Desert national Wildlife Refuge, Nevada, 1990-1991 (N = No. Locations).

yearling male, and in proportion to availability by the yearling female.

Use of east side midslopes increased in spring compared to summer, fall, and winter seasons. Females used east midslopes more than expected during the spring season. Though use of east midslope associations by males increased in spring, use was still less than expected based on availability.

4.3 SLOPE

Mountain sheep were observed on 2 slope classes (36-60 and 61-80%) more than others (Table 4). Middle slope areas (36-80%) represented 31.3% of available terrain (Fig. 8), and contained 53.5% of all locations. Use of 5 slope classes differed from availability ($P < 0.0001$). Areas of ≤36% slope were used less than expected based on availability ($P < 0.05$) in all seasons by all sheep, while slopes ≥80% were used as expected based on availability.

4.4 THERMAL COVER

Thermal cover was most abundant where it was provided by topography in steep canyons and on north-facing slopes. Thermal cover available from vegetation structure was limited to joshua trees and large creosote bushes (*Larrea tridentada*). Joshua trees on the west bajada represent 22.14% of available plant cover for that association, and were used by bedded mountain sheep for thermal cover during 20.2% of observations of bedded individuals.

4.5 RESOURCE USE

Mountain sheep selected habitats on the western side of the mountain for foraging (n = 1,068, Table 5), with 91% of the forage sites (n = 539) having slopes between 25 and 75%. The bajada (< 1,219 m) and ridgetop (> 1,324 m) were used less for foraging than expected based on availability in the enclosure,

Table 4. Relative Availability, Percent Use, and Bonferroni Confidence Intervals for 5 Slope Classes in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Slope class (%)	Avail-ability	Expected use	Actual use	Bonferroni CI	Use[a]
0-10	0.219	0.219	0.066	$0.036 \leq P1 \leq 0.096$	<
11-36	0.365	0.365	0.286	$0.236 \leq P2 \leq 0.336$	<
37-60	0.195	0.195	0.361	$0.311 \leq P3 \leq 0.411$	>
61-80	0.118	0.118	0.174	$0.134 \leq P4 \leq 0.214$	>
>80	0.103	0.103	0.112	$0.082 \leq P5 \leq 0.142$	=

[a] <, >, and = represent use less than, greater than, and equal in proportion to availability, respectively.

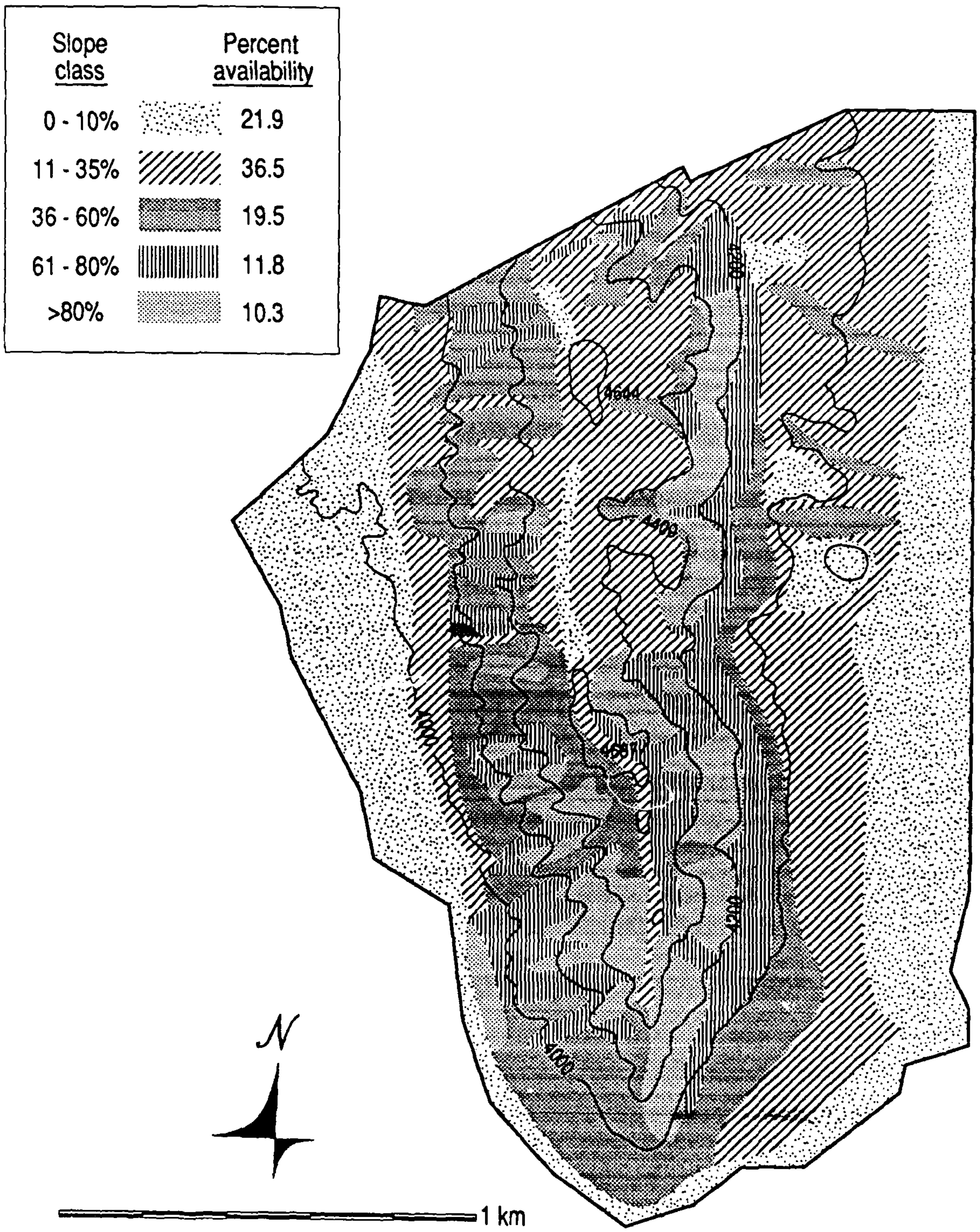

Figure 8. Distribution and Availability of 5 Slope Classes in a 320-ha Mountain Sheep Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1992

and the lower (1,220 to 1,280 m) and upper (1,281 to 1,341 m) midslope elevations were used greater than they were expected based on availability ($P < 0.05$).

Males and females used each forage class differently between seasons (Table 6). Males and females used browse more in spring, and less in fall, than in any other season. Both groups used grass more in fall, and least in spring. Forb use was greatest for males and females in winter. Females used significantly more forbs than males in winter ($W = 10$; 4,8 df; $P < 0.01$; Table 6). Females foraged at locations with more forbs during winter ($W = 11$; 4,8 df; $P < 0.05$), and more grass during spring ($W = 12$; 4,8 df; $P < 0.05$) than male foraging locations. Only the availability of grass at the foraging sites of male ($H = 7.35$, 2 df, $P < 0.05$) and female ($H = 7.44$, 2 df, $P < 0.05$) sheep differed between seasons, peaking in fall for both groups.

Male and female sheep used browse less than expected, and forbs and grasses were used greater than or equal to expectancy, based on availability in every season examined (Table 7). Dominant (dominant animals were those that displaced another animal from a resource [Zine 1992]) and subordinate groups did not differ in forage selection in any season (Table 8). The dominants use of browse, forbs, and grasses varied between seasons ($H = 13.52$, df = 3, $P > 0.05$; $H = 11.82$, df = 3, $P > 0.05$; respectively) (Table 8). Browse use by dominants was greatest in spring and lowest in fall. Forb use was greatest in winter and lowest in summer. Grass use was greatest in fall and lowest in spring. The subordinates also varied seasonally in their use of browse ($H = 18.63$, df = 3, $P < 0.05$), forbs ($H = 18.36$, df = 3, $P < 0.05$), and grasses ($H = 22.61$, df = 3, $P < 0.05$) (Table 8). The use of browse, forbs, and grasses by subordinates was similar to the use by dominants, with the exception that forb use was at its lowest in fall. Both groups used browse species less than expected based on availability, and forb and grass species greater than,

Table 5. Habitat Use by Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Habitat[a]	% expected Use	% observed Use	Bonferroni confidence internal	U/A[b]
1	9	15	0.15 ± 0.030	>
2	16	35	0.30 ± 0.040	>
3	9	26	0.26 ± 0.037	>
4	2	1	0.01 ± 0.008	<
5	10	9	0.09 ± 0.024	=
6	18	10	0.10 ± 0.025	<
7	28	4	0.04 ± 0.017	<
8	6	1	0.01 ± 0.008	<
9	3	<1	0.004 ± 0.005	<

[a] 1 = west bajada, 2 = west midslope, 3 = west drainage, 4 = ridgetop, 5 = east drainage, 6 = east midslope, 7 = east bajada, 8 = blackbrush, 9 = flats.

[b] Use relative to availability assessed at the 0.05 level of significance for each comparison, following Byers et al. (1984); >, <, and = represent use greater than, less than, and equal in proportion to availability, respectively.

Table 6. Forage Class (Median %) Use by Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

	Diet					
	Browse		Forb		Grass	
Season	M	F	M	F	M	F
Summer[a]	30.00	29.45	0.00	2.35	70.00	65.80
Fall	18.35	14.65	1.05	2.30	81.65	83.20
Winter	31.35	32.45	4.40	14.80	64.25	52.00
Spring	55.55	52.40	21.95	13.75	19.45	34.55
P[b]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

[a] Summer = Jun-Aug, fall = Sep-Nov, winter = Dec-Feb, spring = Mar-May.

[b] Kruskall-Wallis one-way ANOVA results of forage class use by season.

Table 7. Forage Use by Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Season[a]	Sex	Forage[b] type	Expected use (%)	Observed use (%)	U/A[c]
Fall	M	Br	68	23	<
	F	Br	74	37	<
	M	Fb	3	3	=
	M	Fb	4	3	=
	M	Gr	29	74	>
	F	Gr	22	61	>
Winter	M	Br	74	29	<
	F	Br	76	31	<
	M	Fb	3	4	=
	F	Fb	3	15	>
	M	Gr	24	67	>
	F	Gr	21	54	>

Table 7. Continued.

Season[a]	Sex	Forage[b] type	Expected use (%)	Observed use (%)	U/A[c]
Spring	M	Br	84	55	<
	F	Br	77	53	<
	M	Fb	4	25	>
	F	Fb	3	15	>
	M	Gr	12	20	=
	F	Gr	19	32	>

[a] Fall = Sep-Nov, winter = Dec-Feb, spring = Mar-May.

[b] Br = browse, Fb = forb, Gr = grass.

[c] Use relative to availability measured at the 0.05 level of significance for each comparison, following Byers et al. (1984); <, >, and = represent greater than, less than, and equal in proportion to availability, respectively.

Table 8. The Vegetation Use (Median %) of Dominant and Subordinate Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Season[a]	Forage type: Browse	Forb	Grass
Summer			
Dominant	35.25	0.00	64.75
Subordinate	29.20	2.70	66.70
P	0.40	0.26	0.78
Fall			
Dominant	16.70	2.10	83.10
Subordinate	15.20	1.90	83.30
P	0.42	1.00	0.47
Winter			
Dominant	35.30	5.10	59.30
Subordinate	32.40	14.60	52.50
P	0.75	0.05	0.19
Spring			
Dominant	50.00	22.20	22.20
Subordinate	52.60	13.50	34.00
P	0.87	0.10	0.26

[a] Summer = Jun-Aug 1990, fall = Sep-Nov 1990, winter = Dec 1990-Feb 1991, spring = Mar-May 1991.

[b] Mann-Whitney U tests calculated on the percent use of each forage class for each individual. Dominant *n* = 5, subordinate *n* = 7.

or equal to expectancy based on their availability, in every season (Table 9).

Subordinates foraged in areas that had more grass during spring (W = 16; df = 5,7; $P < 0.01$), and more forbs during winter (W = 15; df = 5,7; $P < 0.01$), than the areas dominants foraged in. The area of available grass (H = 9.5, df = 2, $P < 0.05$) differed at the foraging sites of dominant individuals between seasons; peaking in availability during fall and least available during spring. The availability of browse, forbs, and grasses at the foraging sites of subordinates did not vary seasonally.

4.6 ACTIVITY

Dominants spent a greater percent of their time in social interactions than the subordinates in every season except summer (Table 10). Dominants spent more time bedded (and a greater percent of that activity in the shade than subordinates), while foraging less during spring than subordinates (Table 10). Subordinates differed in the percent time bedded, bedded in the shade, standing, and moving between seasons (F = 4.88, 3,909 df, $P < 0.01$; F = 17.92, 3,909 df, $P < 0.001$; F = 9.53, 3,909 df, $P < 0.001$; F = 7.68, 3,909 df, $P < 0.001$, respectively) (Table 10). Dominants also varied seasonally in the percent time spent bedded (F = 5.14, 3,505 df, $P < 0.01$), bedded in the shade (F = 11.64, 3,505 df, $P < 0.001$), standing (F = 6.12, 3,505 df, $P < 0.001$), and socially interacting (F = 3.22, 3,505 df, $P < 0.05$) (Table 10). Dominant and subordinate groups spent more time bedded in the shade in summer than in any other season. Dominants spent more time bedded in spring and subordinates bedded more in winter, than in any other season. Dominant individuals spent more time in social activity in fall than in any other season.

Table 9. Forage Use by Mountain Sheep (D = Dominant, S = Subordinate) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Season[a]	Hierarchy level[b]	Forage type[c]	Expected use (%)	Observed use (%)	Use vs. availability[d]
Fall	D	Br	67	20	<
	S	Br	75	15	<
	D	Fb	3	4	=
	S	Fb	4	3	=
	D	Gr	30	77	>
	S	Gr	21	82	>
Winter	D	Br	74	33	<
	S	Br	76	30	<
	D	Fb	2	7	=
	S	Fb	3	15	>
	D	Gr	24	60	>
	S	Gr	21	56	>

Table 9. Continued.

Season[a]	Hierarchy level[b]	Forage type[c]	Expected use (%)	Observed use (%)	Use vs. availability[d]
Spring	D	Br	86	54	<
	S	Br	76	53	<
	D	Fb	3	21	>
	S	Fb	3	16	>
	D	Gr	11	25	>
	S	Gr	21	32	>

[a] Fall = Sep-Nov 1990, winter = Dec 1990-Feb 1991, spring = Mar-May 1991.

[b] Hierarchy level based on calculated dominance value score (Bielharz and Mylreas 1963).

[c] Br = browse, Fb = forb, Gr = grass.

[d] Use relative to availability measured at the 0.05 level of significance for each comparison, following Byers et al. (1984); <, >, and = represent greater than, less than, and equal in proportion to availability, respectively.

Table 10. Activity Budgets (%) of Dominant and Subordinate Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

	Activity[a]					
Season[b]	For	Bed	Bsh[c]	Std	Mov	Soc
Summer						
Dominant	34.89	43.40	89.60	14.41	5.38	1.56
Subordinate	35.84	40.69	72.71	15.96	6.72	0.53
P[d]	0.99	0.89	0.37	0.58	0.39	0.17
Fall						
Dominant	31.29	45.38	64.12	16.63	3.64	2.60
Subordinate	36.24	41.35	55.49	17.50	4.38	0.30
P	0.08	0.18	0.30	0.58	0.81	<0.01
Winter						
Dominant	32.04	51.40	13.09	11.74	3.05	1.50
Subordinate	37.73	45.75	11.13	12.88	2.89	0.27
P	0.28	0.45	0.91	0.37	0.73	<0.01

Table 10. Continued.

	Activity[a]					
Season[b]	For	Bed	Bsh[c]	Std	Mov	Soc
Spring						
Dominant	31.99	52.35	37.12	9.46	4.69	1.09
Subordinate	42.40	41.65	31.17	11.92	3.18	0.27
P	0.01	0.01	0.02	0.43	0.24	<0.01

[a] For = foraging, Bed = bedding, Bsh = bedding in the shade, std = standing, mov = moving, soc = socially interacting with another individual.

[b] Summer = Jun-Aug 1990, fall = Sep-Nov 1990, winter = Dec 1990-Feb 1991, spring = Mar-May 1991.

[c] Bsh = % time that bedding was in the shade.

[d] *t*-test used to compare groups after the percent data was transformed with the square-root arcsine transformation.

4.7 CALIBRATION

During the calibration of the enclosure, F-16 aircraft created 5 noise zones when properly flying along the flight path. The highest sound level (106-110 dB) was restricted to a small patch at the top of the ridge. The remainder of the ridge received 100-105 dB. This zone was surrounded by a broader zone of 95-100 dB followed by a 90-95 dB zone. The flats were fartherest from the flight path and received 85-90 dB (Appendix A, figure 6). The ambient sound environment that mountain sheep were accustomed to was approximately 65 dB (Appendix A, appendix c) 3 seconds prior to overflights.

4.8 OVERFLIGHTS

We scheduled approximately 60 overflights/treatment period (1/weekday, ≥5/weekday, ≥5/weekday, 1/weekday for the 4 weeks, respectively) (Table 11). Some scheduled overflights were not available to fly over the study area due to higher USAF priorities. We obtained 111, 57, and 74 overflights in periods 1, 2, and 3, respectively, to document the influence that F-16 aircraft had on mountain sheep (Table 11).

Although we obtained or exceeded the expected number of overflights/treatment period we were not able to examine the response of sheep to all of them. Only 1 sheep was observed/overflight and ≤2 biologists/overflight made observations. Sheep were not always located and sometimes when locations were made the sheep were in a position where the heart rate signals were unclear. Often sheep were on the ridges and would move to the opposite side as they foraged making observations or heart rate signal interpretation impossible. In addition, the heart rate monitor for female 4570 failed in the middle of the first treatment period. We obtained overflight information for 3 animals (1M, 2F). We recorded 45 reactions of male 4270 during periods 1 and 2 (Table 12), 31 reactions of

Table 11. F-16 Aircraft Overflights Recorded Over the 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Flight description	Periods 1 24 May-27 Jul 1991	Periods 2 29 Sep-20 Nov 1991	Periods 3 4 Feb-2 Apr 1992	Total
Good flights[a]	67	34	42	143
Off line[b]	44	23	32	99
Totals	111	57	74	242

[a] Aircraft at the proper elevation, flying at 90% power along the desired flight path.

[b] Aircraft at the proper elevation, flying at 90% power, ≥200 m off the desired flight path.

Table 12. Distribution of Overflights by F-16 Aircraft Over an Adult Male Mountain Sheep (No. 4270) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

	Flight[b]	Sound[c]	Activity[d]						
Period[a]	quality	zone	Bd	Fg	St	Wk	Rn	Unknown	Total
1	1	1			1				1
		2	3		6			1	10
		3			1			5	6
		4			1				1
		5							0
		Total	3	0	9	0	0	6	18
1	2	1							0
		2	5		1				6
		3	2						2
		4						1	1
		5							0
		Total	7	0	1	0	0	1	9
2	1	1			1			1	2
		2		1	2				3
		3			1				1
		4			2	1		2	5
		5							0
		Total	0	1	6	1	0	3	11

Table 12. Continued.

Period[a]	Flight[b] quality	Sound[c] zone	Activity[d] Bd	Fg	St	Wk	Rn	Unknown	Total
	2	1			1				1
		2							0
		3							0
		4			2			4	6
		5							0
		Total	0	0	3	0	0	4	7
Grand total		1	0	0	3	0	0	1	4
		2	8	1	9	0	0	1	19
		3	2	0	2	0	0	5	9
		4	0	0	5	1	0	7	13
		5	0	0	0	0	0	0	0
	Grand total		10	1	19	1	0	14	45

[a] Period: 1 = 24 May-27 Jul 1991, 2 = 29 Sep-2 Nov 1991, 3 = 4 Feb-2 Apr 1992.

[b] Flight quality: 1 = good overflight, 2 = off line.

[c] Sound zone: 1 = 85 - 90 dB, 2 = 90 - 95 dB, 3 = 95 - 100 dB, 4 = 100 - 105 dB, 5 = 105 - 110 dB.

[d] Activity at the time of the overflight: Bd = bedding, fg = foraging, st = standing, wk = walking, rn = running.

female 5010 during period 1 (Table 13), and 73 reactions of female 4322 during periods 1, 2, and 3 (Table 14) to F-16 overflights.

None of the overflights occurred while animals were in zone 5 (106-110 db). Zone 5 was a small area at the top of the enclosure (Appendix A, figure 6). We documented the reaction of sheep to overflights 12, 62, 31, and 44 times in sound zones (Appendix A, figure 6) 1, 2, 3, and 4, respectively (Tables 12, 13, 14).

4.9 COMPARISON OF BEHAVIOR OF MOUNTAIN SHEEP WITHIN THE BASELINE PERIOD (MAY 1990-MAY 1991) TO COMPARABLE TIMES WITHIN THE TREATMENT (JUN 1991-APR 1992)

Prior to each treatment overflight we collected behavioral data for ≤7 days to contrast with comparable data from the baseline period. During period 1 there were significant differences in the amount of time sheep spent in various activities during the baseline and treatment periods (Table 15). Similar differences were found between activity budgets in the baseline and treatment for periods 2 (Table 16) and 3 (Table 17).

The significant differences ($\underline{P} < 0.05$) in the amount of time mountain sheep were observed bedding, foraging, standing, walking, and running during the first year in the enclosure and the second year can be attributed to the differences in data collection, population composition, and perhaps factors we did not measure. During the first year of the study we documented habitat use and behavior of the entire population but during the second year our observations were limited to specific individuals (i.e., those with heart rate monitors). Sample sizes were, therefore, different between the years. The composition of the population also changed between years. In May 1990 12 sheep were placed in the enclosure. By April 1991 they produced 6 lambs and in May 1992 4 adults were placed inside the enclosure (N = 22).

Table 13. Distribution of overflights by F-16 Aircraft Over an Adult Female Mountain Sheep (No. 5010) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

	Flight[b]	Sound[c]	Activity[d]						
Period[a]	quality	zone	Bd	Fg	St	Wk	Rn	Unknown	Total
1	1	1		1			3		4
		2	4		4		3		11
		3			1				1
		4			3		1	1	5
		5							0
		Total	4	1	8	0	7	1	21
1	2	1							0
		2	2		2				4
		3			1		1		2
		4			2	1	1		4
		5							0
		Total	2	0	5	1	2	0	10

Table 13. Continued.

Period[a]	Flight[b] quality	Sound[c] zone	Activity[d] Bd	Fg	St	Wk	Rn	Unknown	Total
Grand Total		1	0	1	0	0	3	0	4
		2	6	0	6	0	3	0	15
		3	0	0	2	0	1	0	3
		4	0	0	5	1	2	1	9
		5	0	0	0	0	0	0	0
		Grand Total	6	1	13	1	9	1	31

[a] Period: 1 = 24 May-27 Jul 1991, 2 = 29 Sep-2 Nov 1991, 3 = 4 Feb-2 Apr 1992.

[b] Flight quality: 1 = good overflight, 2 = off line.

[c] Sound zone: 1 = 85 - 90 dB, 2 = 90 - 95 dB, 3 = 95 - 100 dB, 4 = 100 - 105 dB, 5 = 105 - 110 dB.

[d] Activity at the time of the overflight: Bd = bedding, fg = foraging, st = standing, wk = walking, rn = running.

Table 14. Distribution of Overflights by F-16 Aircraft Over an Adult Female Mountain Sheep (No. 4322) in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Period[a]	Flight[b] quality	Sound[c] zone	Activity[d] Bd	Fg	St	Wk	Rn	Unknown	Total
1	1	1		1	2				3
		2	1		6	1	3		11
		3			2		1		3
		4			2				2
		5							0
		Total	1	1	12	1	4	0	19
	2	1							0
		2		1	2		1		4
		3			2			1	3
		4					1		1
		5							0
		Total	0	1	4	0	2	1	8
2	1	1							0
		2			2	1		1	4
		3			2				2
		4			1		1	3	5
		5							0
		Total	0	0	5	1	1	4	11

Table 14. Continued.

Period[a]	Flight[b] quality	Sound[c] zone	Activity[d] Bd	Fg	St	Wk	Rn	Unknown	Total
	2	1			1				1
		2			3				3
		3		1				1	2
		4					1	2	3
		5							0
		Total	0	1	4	0	1	3	9
3	1	1							0
		2			1		1	1	3
		3			2				2
		4			7			1	8
		5							0
		Total	0	0	10	0	1	2	13
	2	1							0
		2			2		1		3
		3			6	1			7
		4			3				3
		5							0
		Total	0	0	11	1	1	0	13

Table 14. Continued.

Period[a]	Flight[b] quality	Sound[c] zone	Activity[d] Bd	Fg	St	Wk	Rn	Unknown	Total
Grand total		1	0	1	3	0	0	0	4
		2	1	1	16	2	6	2	28
		3	0	1	14	1	1	2	19
		4	0	0	13	0	3	6	22
		5	0	0	0	[illegible]	0	0	0
Grand total			1	3	46	3	10	10	73

[a] Period: 1 = 24 May-27 Jul 1991, 2 = 29 Sep-2 Nov 1991, 3 = 4 Feb-2 Apr 1992.

[b] Flight quality: 1 = good overflight, 2 = off line.

[c] Sound zone: 1 = 85 - 90 dB, 2 = 90 - 95 dB, 3 = 95 - 100 dB, 4 = 100 - 105 dB, 5 = 105 - 110 dB.

[d] Activity at the time of the overflight: Bd = bedding, fg = foraging, st = standing, wk = walking, rn = running.

Table 15. Contingency Table Summary Comparing Times Within Summer (Jun-Jul 1990) Baseline and Treatment (Period 1, 24 May-27 Jun 1991) Activity Budgets (%) of Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{O-E^2}{E}$	X^2[c]
Pre-flight: Contingency table X^2 = $P < 0.0001$							
1	Bd	25	30.5	38.75	31.78	1.45	1.7
2		511	47.0		421.21	0.25	
1	Fg	44	53.7	38.55	31.61	4.86	69.9***
2		254	23.4		419.04	65.0	
1	St	10	12.2	15.1	12.38	0.46	6.6**
2		196	18.0		164.14	6.18	
1	Wk	3	3.7	7.65	6.27	1.71	23.8***
		126	11.6		83.16	22.07	
Flight 3[d]: Contingency table X^2 = $P > 0.05$							
1	Bd	34	42.0	40.35	32.68	0.05	2.0
2		1,082	38.7		1,128.99	1.96	
1	Fg	33	40.7	35.5	28.76	0.63	21.6***
2		849	30.3		993.29	20.96	
1	St	12	14.8	18.3	14.82	0.54	19.7***
2		611	21.8		512.03	19.13	

Table 15. Continued.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{(O-E)^2}{E}$	X^2 [c]
1	Wk	2	2.5	5.4	4.37	1.29	45.7***
2		233	8.3		151.09	44.41	
1	Rn	0	0	0.4	0.32	0.32	12.8***
2		12	0.8		11.19	12.45	
Post-flight: Contingency table X^2 = P > 0.0001							
1	Bd	31	16.1	28.15	54.33	10.02	53.4***
2		337	40.2		235.90	43.33	
1	Fg	91	47.2	41.25	79.61	1.63	8.8**
2		296	35.3		345.68	7.14	
1	St	39	20.2	19.85	38.31	0.01	0.1
2		163	19.5		166.34	0.07	
1	Wk	32	16.6	10.8	20.84	5.98	32.9***
2		42	5.0		90.50	25.99	

[a] Data period 1 = baseline data collected during Jun-Jul 1990, 2 = treatment data collected within 12 Jun-17 Jul 1991.

[b] Activity Bd = bedded, Fg = foraging, St = standing, Wk = walking, Rn = running.

[c] Level of significance: * = 0.05, ** = 0.01, *** = 0.001.

[d] The overflights occurred from 19 Jun 1991 to 12 Jul 1991.

Table 16. Contingency Table Summary Comparing Times Within Fall (Oct-Nov 1990) Baseline and Treatment (Period 2, 29 Sep-2 Nov 1991) Activity Budgets (%) of Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{O-E^2}{E}$	X^{2c}
Pre-flight: Contingency table X^2 = $\underline{P}$ < 0.0001							
1	Bd	114	27.5	34.45	142.62	5.74	18.7***
2		383	41.4		318.66	12.99	
1	Fg	181	43.7	38.95	161.25	2.42	7.9**
2		316	34.2		360.29	5.45	
1	St	68	16.4	18.0	74.52	0.57	1.8
2		181	19.6		166.5	1.26	
1	Wk	51	12.3	8.4	34.78	7.56	24.0***
2		42	4.5		77.7	16.4	
1	Rn	0	0	0.15	0.62	0.62	2.49
2		3	0.3		1.39	1.87	
Flight 3[d]: Contingency table X^2 = $\underline{P}$ > 0.05							
1	Bd	120	33.7	35.5	126.38	0.32	1.9
2		609	37.3		579.0	1.55	
1	Fg	112	31.5	31.65	112.67	0.004	0.02
2		519	31.8		516.21	0.02	
1	St	92	25.8	24.7	87.93	0.10	1.0
2		385	23.6		402.86	0.79	

Table 16. Continued.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{O-E^2}{E}$	X^{2c}
1	Wk	32	9.0	7.6	26.88	0.98	5.3*
2		100	6.1		123.14	4.35	
1	Rn	0	0	0.5	1.96	1.96	11.1***
2		18	1.1		8.97	9.09	
Post-flight: Contingency table X^2 = P > 0.01							
1	Bd	33	28.7	37.85	43.53	2.55	23.4***
2		444	47.0		357.68	20.83	
1	Fg	43	37.4	34.65	39.85	0.25	2.4
2		301	31.9		327.44	2.13	
1	St	28	24.3	20.45	23.52	0.85	7.7**
2		157	16.6		193.25	6.80	
1	Wk	11	9.6	6.95	7.99	1.13	10.4**
2		41	4.3		65.68	9.27	
1	Rn	0	0	0.1	0.12	0.12	1.3
2		2	0.2		0.95	1.18	

[a] Data period 1 = baseline data collected during Oct-Nov 1990, 2 = treatment data collected within 9 Oct-13 Nov 1991.

[b] Activity Bd = bedded, Fg = foraging, St = standing, Wk = walking, Rn = running.

[c] Level of significance: * = 0.05, ** = 0.01, *** = 0.001.

[d] The overflights occurred from 16 Oct 1991 to 6 Nov 1991.

Table 17. Contingency Table Summary Comparing Times Within Winter (Feb-Mar 1990) Baseline and Treatment (Period 3, 4 Feb-2 Apr 1992) Activity Budgets (%) of Mountain Sheep in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{(O-E)^2}{E}$	X^2[c]
Pre-flight: Contingency table X^2 = $\underline{P}$ < 0.05							
1	Bd	116	34.3	34.3	115.93	<0.01	<0.01
2		212	34.3		211.97	<0.01	
1	Fg	114	33.7	36.0	121.68	0.49	1.4
2		237	38.3		222.48	0.95	
1	St	84	24.9	23.45	79.26	0.28	0.83
2		136	22.0		144.92	0.55	
1	Wk	24	7.1	0.06	20.96	0.44	1.2
2		33	5.3		38.32	0.74	
Flight 3[d]: Contingency table X^2 = $\underline{P}$ > 0.001							
1	Bd	207	38.5	35.7	191.71	1.22	5.1*
2		596	32.9		645.81	3.84	
1	Fg	199	37.1	35.35	189.83	0.44	2.1
2		607	33.6		639.48	1.65	
1	St	94	17.5	21.6	115.99	4.17	18.3***
2		465	25.7		390.74	14.11	
1	Wk	37	6.9	6.8	36.52	0.01	0.04
2		121	6.7		123.01	0.03	

Table 17. Continued.

Data period[a]	Activity[b]	Observed (O) n	Observed (O) %	Mean (%) of period 1 & 2	Expected (E)	$\frac{O-E^2}{E}$	X^2 [c]
1	Rn	0	0	0.55	2.95	2.95	13.1***
2		20	1.1		9.95	10.15	
Post-flight: Contingency table X^2 = $\underline{P}$ > 0.05							
1	Bd	42	32.1	37.05	48.54	0.88	5.8*
2		316	42.0		278.99	4.91	
1	Fg	53	40.5	40.35	52.86	<0.01	<0.01
2		303	40.2		303.84	<0.01	
1	St	26	19.8	16.2	21.22	1.08	7.1**
2		95	12.6		121.99	5.97	
1	Wk	10	7.6	6.4	8.38	0.31	2.1
2		39	5.2		48.19	1.75	

[a] Data period 1 = baseline data collected during Feb-Mar 1991, 2 = treatment data collected within 17 Feb-26 Mar 1992.

[b] Activity Bd = bedded, Fg = foraging, St = standing, Wk = walking, Rn = running.

[c] Level of significance: * = 0.05, ** = 0.01, *** = 0.001.

[d] The overflights occurred from 24 Feb 1992 to 19 Mar 1992.

By the end of the year 7 more lambs were born increasing the population to 29.

Although we were not able to demonstrate that behavior of the sheep was consistent between years we did conclude that the behavior of our population was consistent with that of free-ranging populations (Zine 1992). The animals in the enclosure also used the habitats similar to the way that free-ranging sheep used habitats (Berner 1992). We conclude that animals in the enclosure were adjusted to the enclosure. Because of the differences in data collection between years and the increased population over time we were not able to use the first year's data as true baseline data. Instead, we assumed the population was adjusted to the enclosure and examined the sheep 15 minutes before overflights, as baseline data, overflights, and as long after overflights as necessary to document reactions to them. This allowed us to document actual reactions to overflights.

4.9.1 Activity and Overflights

Adult Male 4270.--There was no difference in bedding and foraging prior to or after overflight in period 1. However, there was more standing after overflights than before and less walking. During period 2 there were no differences in any activity before or after overflights. During period 3 this male bedded more after overflights and spent less time foraging (Table 18).

Adult Female 5010.--There was a significant difference ($P < 0.05$) in bedding and foraging during period 1 (Table 19). This female bedded more prior to overflights and foraged more after overflights. There was no significant difference in other activities.

Adult Female 4322.--During period 1 this female foraged significantly more after the overflights than before but walked less (Table 20). There was no significant difference between the

Table 18. Activity (%) of an Adult Male Mountain Sheep (No. 4270) Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Period and	Pre		Overflight		Post	
activity	No. obs.	%	No. obs.	%	No. obs.	%
(1) 24 May-27 Jul 1991						
Bedded	153	62.4	491	57.4	161	54.4
Forage	37	15.1	137	16.0	71	24.0
Stand*[a]	24	9.8	168	19.6	57	19.3
Walk***	31	12.7	58	6.8	7	2.4
Run			1	0.1		
(2) 29 Sep-20 Nov 1991						
Bedded	209	44.8	314	41.3	239	48.9
Forage	137	29.4	267	35.1	156	31.9
Stand	95	20.4	134	17.6	69	14.1
Walk	22	4.7	42	5.5	24	4.8
Run	3	0.6	3	0.4	1	0.2
(3) 4 Feb-2 Apr 1992						
Bedded*	52	40.6	162	42.5	85	60.3
Forage	56	43.8	109	28.6	33	23.4
Stand	13	10.2	109	20.5	18	12.8
Walk	7	5.5	31	8.1	5	3.5
Run			1	0.3		

[a] Pre- and -post overflight activity significantly different at the 0.05 level (*), 0.01 level (**), and 0.001 level (***).

Table 19. Activity (%) of 2 Adult Female Mountain Sheep (Nos. 5010, 4750) Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Period and	Pre		Overflight		Post	
activity	No. obs.	%	No. obs.	%	No. obs.	%
No. 5010						
Bedded*	130	46.8	266	27.5	71	27.0
Forage*	79	28.4	392	40.5	122	46.4
Stand	44	15.8	226	23.3	54	20.5
Walk	25	9.0	71	7.3	16	6.1
Run	0	0.0	13	1.3	0	0.0
No. 4750						
Bedded	116	39.6	0	0.0		
Forage	70	23.9	15	40.5		
Stand	72	24.6	12	32.4		
Walk	35	11.9	10	27.0		

* $P \leq 0.05$.

Table 20. Activity (%) of a Female Mountain Sheep (No. 4322) Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Period and activity	Pre No. obs.	Pre %	Overflight No. obs.	Overflight %	Post No. obs.	Post %
(1) 24 May-27 Jul 1991						
Bedded	108	43.5	325	34.7	105	37.6
Forage*	51	20.6	305	32.6	103	36.9
Stand	54	21.8	204	21.8	52	18.6
Walk*	35	14.1	94	10.0	19	6.8
Run	0	0.0	9	1.0	0	0.0
(2) 29 Sep-20 Nov 1991						
Bedded	174	37.9	295	34.4	205	45.0
Forage	179	39.0	248	28.9	145	31.8
Stand	86	18.7	242	28.2	88	19.3
Walk	20	4.4	58	6.8	17	3.7
Run	0	0.0	14	1.6	1	0.2
(3) 4 Feb-2 Apr 1992						
Bedded	149	34.4	254	24.9	175	38.9
Forage*	141	32.6	386	37.8	200	44.4
Stand*	117	27.0	299	29.3	48	10.7
Walk	26	6.0	68	6.7	27	6.0
Run	0	0.0	13	1.3	0	0.0

[a] Pre- and -post overflight activity significantly different at the 0.05 level (*), 0.01 level (**), and 0.001 level (***).

other behaviors. During period 2 there were no significant differences between behaviors before or after overflights (Table 20). During period 3 this female foraged more after overflights but spent less time standing (Table 20).

4.9.2 Heart Rates and Overflights

We compared the recorded heart rates for all 4 instrumented mountain sheep in 24 May-27 July 1991, and between the male and female 4322 in 29 September to 20 November 1991 with a one-way ANOVA. There was a significant difference ($P < 0.001$) among sheep so we examined each one separately.

Adult Male 4270.--The heart rate of this male was significantly higher prior to overflights in both periods than after the overflight occurred (Table 21). However, all values are within the range of heart rate values reported for mountain sheep in various activities prior to being exposed to any subsonic noise (Krausman et al. 1992) (Table 22).

Adult Female 5010.--The heart rate of this female was significantly higher ($P < 0.001$) prior to overflights than after overflights in period 1 (Table 23). However, all values are within the range of heart rate values reported for mountain sheep in various activities prior to being exposed to any subsonic noise (Krausman et al. 1992) (Table 22).

Adult Female 4322.--We recorded heart rates that were significantly ($P < 0.0001$) higher prior to overflights in periods 1 and 2 compared to after the flights. In period 3 the overall heart rate was higher after overflights compared to heart rates prior to overflights (Table 24). As with the other animals all heart rates were within the normal range for each activity reported for mountain sheep prior to being exposed to any subsonic noise (Krausman et al. 1992) (Table 22).

Table 21. Heart Rates (Beats/15 Sec) of an Adult Male Mountain Sheep (No. 4270) in selected activities Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991.

Period and	Heart rate								
	Pre[a]			Overflight			Post		
activity	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE
19 Jun-12 Jul 1991									
Bedded	152	13.6	1.6	491	13.8	1.3	160	13.3	1.3
Forage	37	17.6	1.9	137	16.8	1.6	7.1	17.2	1.7
Stand	24	16.7	2.5	168	16.3	1.9	57	15.9	2.6
Walk	31	18.8	3.0	58	18.3	2.0	7	18.0	1.3
Run				1	31.0	0.0			
16 Oct-6 Nov 1991									
Bedded	207	14.5	1.4	302	13.6	1.4	232	12.5	1.1
Forage	136	18.3	2.1	264	16.4	2.0	152	16.3	1.8
Stand	94	17.9	2.8	132	16.5	2.4	67	15.6	2.1
Walk	22	21.3	3.2	41	18.0	2.5	21	17.1	2.4
Run	2	21.0	1.4	3	22.7	2.1	1	23.0	0.0

[a] Heart rate is significantly higher prior to overflights in period 1 (P = 0.0196) and period 2 (P = 0.0001) than after overflights in the same period.

Table 22. Mean Heart Rates (Beats/Min) for Mountain Sheep in Various Activities Prior to any Constant Exposure to Subsonic Noise (Krausman et al. 1992) and Heart Rates Averaged Over 5 Days (Workman et al. 1992).

	Activity						
	Krausman et al. (1992)					Averaged over 5 days (Workman et. et al. 1992)	
Heart rate	Walk	Bedded	Standing	Running	Forage	F sheep	M sheep
$\bar{X}$	66.4	50.4	60.0	107.5	60.5	69	74
Range	44-116	32-76	44-88	60-132	40-88		
SE	1.62	0.33	0.53	5.01	0.68	1.3	1.5
No. sheep	4	4	4	3	4	1	2
No. obs.	73	501	306	15	143	5 days	5 days

Table 23. Heart Rates (Beats/15 Sec) for Female Mountain Sheep in Selected Activities Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991.

Period and	Heart rate								
	Pre[a]			Overflight			Post		
activity	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE
Female no. 5010									
19 Jun-12 Jul 1991									
Bedded	129	14.7	1.9	266	13.6	1.4	71	13.0	1.1
Forage	79	17.5	2.0	391	16.3	1.6	122	15.7	1.6
Stand	44	16.3	1.7	224	15.8	1.9	54	14.8	2.5
Walk	25	19.4	2.7	71	17.5	2.1	16	18.4	2.8
Run				12	22.9	3.9			
Female no. 4570[b]									
16 Oct-6 Nov 1991									
Bedded	116	16.2	1.9						
Forage	70	19.9	2.1	15	19.7	1.4			
Stand	72	19.4	2.1	12	18.8	2.1			
Walk	35	22.6	3.1	10	21.2	1.7			

[a] Heart rate is significantly higher prior to overflights in period 1 ($P = 0.001$) prior to overflights for female no. 5010 in Jun-Jul than after overflights in the same period.

[b] Heart rate monitor failed.

Table 24. Heart Rates (Beats/15 Sec) of an Adult Female Mountain Sheep (No. 4322) in Selected Activities Prior to, During, and After Overflights of F-16 Aircraft Over a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991.

Period and	Heart rate								
	Pre[a]			Overflight			Post		
activity	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE
19 Jun-12 Jul 1991									
Bedded	108	16.9	2.0	325	14.3	1.5	105	13.3	1.1
Forage	51	19.7	2.4	295	16.6	2.1	103	17.0	1.9
Stand	54	17.8	2.4	192	16.1	2.2	52	15.2	1.7
Walk	34	19.6	2.1	92	17.3	2.9	19	18.1	2.4
Run				8	23.3	4.8			
16 Oct-6 Nov 1991									
Bedded	174	13.1	1.2	294	12.3	1.3	203	12.1	0.9
Forage	179	16.5	1.6	247	15.4	1.7	144	15.9	2.2
Stand	86	15.1	1.6	236	14.6	2.3	87	14.5	1.9
Walk	20	17.7	2.2	58	17.0	2.1	17	18.6	2.6
Run				7	22.3	6.2	1	21.0	0.0
24 Feb-19 Mar 1992									
Bedded	129	13.7	1.4	243	15.5	1.8	144	17.0	1.2
Forage	120	19.5	2.5	369	20.7	2.9	192	21.8	2.1
Stand	97	15.6	2.9	282	19.2	3.5	48	19.3	2.4

Table 24. Continued.

Period and	Heart rate								
	Pre[a]			Overflight			Post		
activity	$\underline{N}$	$\bar{X}$	SE	$\underline{N}$	$\bar{X}$	SE	$\underline{N}$	$\bar{X}$	SE
Walk	21	20.0	3.5	63	21.7	3.4	22	22.9	2.0
Run				3	24.3	4.0			

[a] Heart rate is significantly ($\underline{P} < 0.0001$) higher prior to overflights in Jun-Jul and Oct-Nov than after overflights in the same period. In Feb-Mar overall heart rate is higher after overflights compared to heart rates prior to overflights.

We examined the statistical differences in heart rate prior to and after the F-16 overflights with stepwise multiple regression. The sound zone the sheep were in and the elapsed time from the overflight did not explain enough of the variation to be included in the regression. The change in heart rate could not be explained by habitat used, activity ($r^2 = 0.34$), or the quality of the flight ($r^2 = 0.35$). The change in heart rate may be explained best by the behavior the animals were engaged in. However, heart rates did not exceed the recorded values for various activities established by Krausman et al. (1992).

4.10 HEART RATE RESPONSES OF MOUNTAIN SHEEP TO F-16 OVERFLIGHTS

We observed F-16 jets fly over mountain sheep 149 times and documented responses 124 times (83%). Heart rates exceeded normal levels only 21 times (16.9%) and only for short periods.

Adult Male 4270.--During period 1 aircraft flew over the adult male 27 (Table 12) times but his heart rate never exceeded normal levels (Krausman et al. 1992). During period 2 jet aircraft caused heart rate to exceed normal levels 2 times, while he was standing. In both cases the heart rate returned to normal within 60 seconds (Table 25, 26).

Adult Female 5010.--We recorded this female's heart rate 31 times as aircraft flew overhead during period 1 (Table 13). On 1 occasion, while she was standing, her heart rate exceeded normal but returned to normal in <60 seconds (Table 25, 26).

Adult Female 4322.--During period 1 we obtained 27 observations of this female as aircraft flew overhead (Table 14). On 1 overflight, while she was standing, her heart rate increased beyond normal limits but we were not able to obtain further heart rates to determine how long the event lasted (Table 25, 26).

Table 25. Mountain Sheep Heart Rate Response to F-16 Overflights When Exceeding Normal Heart Rates[a] in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Sex and animal	Period[b]	n	Activity	Beyond standard[c]	Return to standard[d]	Total time[e]
Ad M						
4270	1	27		0		
	2	18	Standing	1	1	<1
				1	1	<1
Ad F						
5010	1	31	Standing	1	1	<1
Ad F						
4322	1	27	Standing	1	?	?
	2	20	Standing	1	1	<1
	3	26	Bedded	2	4	2
			Forage	1	2	1
				1	2	1
				2	2	<1
				1	2	1
	3	26	Standing	2	4	2
				1	2	1
				1	2	1
				2	2	<1
				1	2	1

Table 25. Continued.

Sex and animal	Period[b]	n	Activity	Beyond standard[c]	Return to standard[d]	Total time[e]
Ad F						
4322	3		Standing	1	2[f]	1
				1	1	<1
				1	1	<1
				1	1	<1
				1	1	<1
				1	1[f]	<1
				1	1	<1
				1	1	<1
				1	3	2
				1	1	<1
				1	2[f]	1

[a] Established heart rate in beats/minute: bedding = 32-76, foraging = 40-96, standing = 40-88, walking = 44-116, running = 60-142 (Krausman et al. 1992).

[b] 1 = 19 Jun-12 Jul 1991, 2 = 16 Oct-6 Nov 1991, 3 = 24 Feb-19 Mar 1992.

[c] Data assessed in 1 minute blocks of time, beginning at the time of the overflight. Beyond standard is the time block in which the heart rate exceeded the baseline heart rates for undisturbed mountain sheep (Krausman et al. 1992).

[d] The time block in which the mountain sheep's heart rate returned to within the standard heart rate ranged for that particular activity (Krausman et al. 1992).

[e] The length of time the heart rate remained above established baseline for undisturbed mountain sheep (Krausman et al. 1992).

[f] The time at which the heart rate for an activity other than the initial activity returned to within baseline range. This was used when activity changed during the recording of data, and when no heart rates for the initial activity were recorded.

Table 26. Heart Rate (HR) Response of 3 Mountain Sheep[a] in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1991-1992.

Sex and animal no.	Period[a]	No. over-flights	No. HR exceed Baseline[b]	% of all HR that return to baseline within 1 min	2 min
Ad M					
4270	All	45	2	100	
	1	27	0		
	2	18	2		
Ad F					
5010	All	31	1	100	
	1	31	1		
Ad F					
4322	All	73	18	71	92
	1	27	1		
	2	20	1		
	3	26	16		

[a] Period 1 = 19 Jun-21 Jul 1991, 2 = 16 Oct-6 Nov 1991, 3 = 24 Feb-19 Mar 1992.

[b] The number of times heart rate exceeded the baseline range established by Krausman et al. (1992) for undisturbed mountain sheep.

In the second period we obtained 20 observations of this female as aircraft flew overhead (Table 14). On 1 overflight, while she was standing, her heart rate increased beyond normal limits but returned to normal in <60 seconds (Table 25, 26).

In the third period we recorded 26 heart rates as F-16's flew over (Table 14). Her heart rate increased above normal 16 times while standing but returned to normal in $\leq$ 60 seconds 14 times, and in $\leq$120 seconds 2 times (Table 25). During the third period this female had a lamb and responded more to overflights. Females with lambs are more vigilant than those without lambs (Etchberger and Krausman, unpubl. data) and more alerted to disturbances. Although we documented increased heart rates more for this female than the other sheep, the increase in heart rate was of short duration.

5.0 DISCUSSION

This study was unique for at least 2 reasons. First, animals were exposed to known and measured noise levels. Previous studies documented responses of animals to aircraft noise but few measured the sound that animals were exposed to. Second, the exposure to noise from low-flying aircraft was controlled.

5.1 HABITAT USE

Studies of large mammals in enclosures suffer from questions concerning the ability to transfer conclusions to free-ranging populations. We cannot entirely overcome the criticisms directed at enclosure studies, but our study was conducted in 1 of the largest existing mountain sheep enclosures. The only other study of mountain sheep habitat use in a large enclosure was conducted by Morgart (1990) in the Virgin Mountains, Arizona. The size and placement of the enclosure for our study and that used by Morgart (1990) ensured that the basic biological needs of mountain sheep could be met (Gysel and Lyon 1980). Such conditions allowed intensive monitoring of habitat use patterns of individual animals for extended periods. Other studies have used smaller enclosures (Howard and DeLorenzo 1975, McCutchen 1975, Bavin 1980, Elenowitz 1984), or provided supplemental feed (Hailey 1971, McCutchen 1975). Furthermore, other enclosure projects have placed less emphasis on ecological questions, instead concentrating primarily on producing stock for release programs.

5.1.1 Habitat Use Patterns

Animals in our study exhibited habitat use patterns that were characteristic of free-ranging mountain sheep. For example, numerous studies reported that adult male and female mountain sheep seasonally segregate, both spatially and by use of habitat (Geist 1971, McQuivey 1978, Lenarz 1979, Tilton and Willard 1982, Burger 1985). Female-juvenile groups are often found on more rugged, precipitous terrain compared with male groups (Geist and Petocz 1977, Lenarz 1979, Leslie and Douglas 1979).

Segregation behavior was observed in our study during winter and spring. During winter (Dec-Feb 1991), adult males used the west bajada and west draw associations more and less than expected, respectively, while adult females used the same 2 associations less and more than expected, respectively. During spring (Mar-May 1991), females used east and west bajada associations less than expected, and east and west mid-slopes more than expected. Males used west bajadas more than expected during the spring season.

Elenowitz (1984) and Morgart (1990) found that females tended to isolate themselves in higher and more rugged terrain during lambing. In our study, females remained isolated from male groups through spring, and used higher elevation areas with abundant escape cover. Males used bajadas and lower mid-slopes during spring.

One hypothesis proposed to explain seasonal segregation during non-breeding seasons is that segregation reduces intraspecific competition for forage resources, and minimizes disturbance of pregnant or lactating females (Geist and Petocz 1977, Lenarz 1979, Seegmiller and Ohmart 1982, Miller and Gaud 1989). Large portions of the study area were not used or used less than their proportion of availability. There are several explanations for low use. Forage availability is an important habitat requirement for mountain sheep (Graham 1971, Browning and Monson 1980, Tilton and Willard 1982, Van Dyke et al. 1983, Krausman and Leopold 1986). Specifically, the availability of perennial bunch grass appears to affect microhabitat suitability (Steel and Workman 1990), and has been used as an index of forage suitability for mountain sheep (Barrett 1964, Ferrier and Bradley 1970, Hansen 1980, Wilson et al. 1980, Holl 1982, Brown 1983). As the percentage of perennial bunch grass increases, the suitability of the area as mountain sheep habitat also increases (Ferrier and Bradley 1970, Hansen 1980, Holl 1982).

Vegetation associations containing <5% grass species were not used for foraging in the enclosure. East and west bajadas had <3% cover of grass species (Table 27). West-side bajadas were the only vegetation association with <5% grass that were used more than expected based on availability. High use on west-side bajadas may have occurred because the bajada was commonly used for bedding activities, the proximity of bed sites to available grass on the midslope, and the location of the water catchment on the west bajada. All other associations with <5% available grass were used less than expected by chance by all sex and age classes in all seasons.

East side midslopes and draws contained >10% grass, but neither association was used until the spring season. Given the favorable forage and topographic conditions in draw and midslope areas on the east side of the study area (i.e., >5% grass cover, abundant escape cover), it is difficult to explain why these areas were generally not used.

Leslie and Douglas (1979) and Douglas and White (1979) documented the importance of free-standing water to mountain sheep in the Mojave Desert. Elenowitz (1984) reported that mountain sheep movements away from water sources were restricted during rainless periods in summer, and that movement patterns expanded after summer rains in New Mexico. The presence of free-standing water on the west bajada seems to have affected movement patterns of mountain sheep in the enclosure. Adult males, particularly during spring and summer, showed a concentration of activity near the water catchment. A similar concentration was observed for adult males during winter.

Although habitat use studies generally agree that forage is selected at the microhabitat level (McQuivey 1978, Holl 1982, Van Dyke et al. 1983, Bates 1982), Steel and Workman (1990) offer 3 possible explanations for situations where forage selection may

Table 27. Relative Availability and Percent Cover of Forage Classes for 9 Vegetation Associations in a 320-ha Enclosure, Desert National Wildlife Refuge, Nevada, 1990-1991.

Vegetation association	Relative availability	% cover of forage classes			
		Shrubs	Grasses	Forbs	Succulents
Ridgetop	0.021	82.94	9.89	4.22	2.94
Blackbrush	0.057	76.78	1.38	t[a]	21.79
Main wash	0.027	98.41	t	t	1.28
West bajada	0.092	74.60	2.95	t	22.10
East bajada	0.277	83.84	2.39	2.76	11.01
West midslope	0.155	80.96	11.63	3.56	3.85
East midslope	0.184	75.41	15.59	2.96	6.04
West draws	0.092	66.29	26.28	4.29	3.14
East draws	0.095	82.8	14.26	1.78	1.17

[a] t = <1%.

not occur at the microhabitat level. The forage base may be homogenous, eliminating the possibility of forage selection (Steel and Workman 1990). Provided a homogenous forage base, mountain sheep should select foraging habitat close to escape cover (Simmons 1980, Steel and Workman 1990). Although mountain sheep locations were concentrated close to escape cover, there were measurable differences in availability of forage classes (i.e., shrubs, grasses, and forbs) in the enclosure.

The second possibility is that the need for security factors exceeded the need for forage (Steel and Workman 1990, Berger 1991). If this explanation is correct, we could expect to see changes in forage use over time in natal habitat (Geist 1967, 1975).

A third possible explanation is that moderate forage quantity may supply adequate nutrition for growth and reproduction, reducing the need for forage site selection. Newly introduced mountain sheep populations may encounter suitable, previously unforaged habitat. In this case, low population density might allow small groups to meet their nutritional needs with less forage than what is available (Caughley 1977, Elenowitz 1984). This explanation is the most likely, as mountain sheep foraged in vegetation associations containing high proportions of graminoids.

As animal numbers increase in the enclosure, the forage base may decline. A declining forage base may increase the impact of forage availability on microhabitat use and result in changes in forage site selection (Caughley 1977). Declining availability of grass species on the west side of the enclosure may explain the increased use of east side midslope and draw associations during the final season of observation. Continued observation of mountain sheep location and activity data in the enclosure may have shown increased use of east midslope and draw areas containing previously unused vegetation.

5.2 USE OF SLOPE CLASSES

Escape cover is defined as steep, rocky terrain on which mountain sheep can safely outdistance or outmaneuver predators (Gionfriddo and Krausman 1986). Mountain sheep require areas of steep, rocky habitat, consisting to a large degree of rugged, broken terrain (Leslie and Douglas 1979, Hansen 1980, Holl 1982, Elenowitz 1984, Krausman and Leopold 1986). Desert races of mountain sheep are rarely found ≥1 km from escape cover (Jorgenson 1974, Hicks and Eider 1979, Bates and Workman 1983, Dodd 1983, Cunningham and Ohmart 1986). Also, the distance between rocky terrain with >60% slope and other habitat components may influence how often such components, such as forage (Leslie 1978, McQuivey 1978), or water (Douglas and White 1979, Leslie and Douglas 1979) are used.

Although all areas of the enclosure were ≤1 km from escape cover, >95% of all mountain sheep locations were ≤0.5 km from areas of escape cover. In our study, sheep used 36-80% slopes more than expected by chance based on availability. Elenowitz (1984) documented that >90% of all mountain sheep locations were within 75 m of escape cover during all seasons.

5.3 ACTIVITY PATTERNS

Activity patterns were crepuscular in all seasons. Krausman et al. (1985b) reported that mountain sheep activity is inversely correlated with ambient temperature. Crepuscular activity is a strategy used by mountain sheep to avoid excessive heat or exposure to direct solar radiation during mid-day hours. Most feeding activities occurred early and late in the day, while the majority of bedding occurred during mid-day. Foraging and bedding patterns were similar for males and females. Similar activity patterns have been documented in other studies of mountain sheep in deserts (Wilson 1968, Golden and Ohmart 1976, Chilelli and Krausman 1981, Krausman et al. 1985b, McCutchen 1984).

Patterns of habitat use in the enclosure used in this study are similar to those described for free-ranging mountain sheep populations in other habitats (Geist and Petocz 1977, Chilelli and Krausman 1981, Elenowitz 1984, Gionfriddo and Krausman 1986, Krausman et al. 1989). In general, mountain sheep foraged in vegetation associations that had >5% escape cover. Segregation of sexes was observed during winter and spring.

5.4 OVERFLIGHTS

During the first year of the study we demonstrated that the sheep in the enclosure used the habitat available to them in a manner similar to free-ranging mountain sheep. Their activity budgets were also similar to free-ranging populations. We are not claiming that the enclosure did not influence the enclosed population. The year in the enclosure, however, did allow the population to habituate and with few exceptions (i.e., use of larger area) their use of habitat and activities were similar to free-ranging mountain sheep in desert environments. We assumed that this habituation precluded enclosure effects when aircraft flew over the area.

We did not receive as many overflight-animal interactions as planned because of scheduling problems, movements of sheep, and our self-imposed limitations (≤2 biologists in the enclosure at 1 time to record information). We were able to obtain consistent information relating to the response of mountain sheep to F-16 overflights. When aircraft flew over sheep at the desired elevation, power, and direction the animals had limited responses in behavior or heart rate. In some cases an animal would stand more and walk less after an overflight (i.e., male 4270) or would bed more and forage less following an overflight (Table 18). In the second period the behavior of male number 4270 was not different before or after overflights. Patterns were similar for the other 3 animals monitored. On 54 occasions overflights caused animals to alter their behavior and run (Tables 18, 19,

20). The longest distance sheep ran that we could record was 40 m. All other running episodes were <10 m. These short distances are much less than those recorded for sheep running from other aircraft (Krausman et. 1983).

Heart rates of sheep also changed as F-16's flew over the area. However, heart rates were higher before overflights; overall heart rates were lower following overflights. The one exception was in February-March 1992 when female 4322 had an overall increase in heart rate following overflights. This female had a lamb during this period and may have been more vigilant than when she was not caring for young. Murphy et al. (1994) also documented that female caribou with young calves "... may be less tolerant of aircraft disturbance than during other times of the year ..." Future research should focus on the responses of females with lambs to aircraft stimuli.

Although heart rates changed, we only documented 39 instances when they exceeded the ranges for various activities they were engaged in (Table 25) established by Krausman et al. (1992) (Table 22). The heart rate returned to normal within 60 seconds 71% of the time, within 120 seconds 92% of the time, and within 180 seconds 96% of the time (Table 26).

Our results are similar to those reported by Krausman et al. (1992) and Workman et al. (1992); mountain sheep reacted to F-16 overflights with alterations in behavior and heart rate but heart rates returned to normal in <180 seconds. Krausman et al. (1992) reported that heart rates increased following subsonic noise whereas we only recorded this 1 time. In all other cases the heart rate decreased. However 96% of the heart rates were back to normal in <180 seconds.

Workman et al. (1992) examined the influence of subsonic overflights of F-16 aircraft on 3 mountain sheep during 2 trials

separated by 1 week. Each trial included several disturbance bouts that lasted approximately 15 minutes and consisted of repeated disturbances by the same type aircraft. They recorded mean elevated heart rates varying from 82 to 159 beats/minute (bpm) lasting 4-20 seconds. The sheep in their study appeared to habituate to overflights and Workman et al. (1992) did not document detrimental influences related to overflights; neither did we.

Krausman et al. (1992) stated that the long-term effects of low-altitude aircraft and related noise on productivity and recruitment is information that is important in determining how these disturbances influence population dynamics. Although our study was not designed to examine these factors we obtained information that suggested the overflights were not detrimental to productivity and recruitment. During 1990-1991 6 lambs were born to 8 females. We do not know if the 2 females without lambs ever gave birth that year but they were never seen with lambs. In 1991-1992 7 of 8 adults gave birth to lambs; we never saw the female that did not appear to give birth with a lamb. The latter year included overflights and in both years productivity and recruitment were much higher than in nearby populations (D. Delaney, NDW, pers. commun.). When the project was terminated and the enclosure removed we were not aware of any mortalities.

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6.0 GENERAL CONCLUSIONS

We were able to meet our objectives and conclude that F-16 aircraft flying over mountain sheep habitat (≤7/day) did not alter behavior in a detrimental manner or cause a chronic increase in heart rate. We have five general conclusions.

1. Patterns of habitat use by mountain sheep in the 3.2 km^2 enclosure were similar to habitat use described for free-ranging mountain sheep in other areas (Geist and Petocz 1977, Chilelli and Krausman 1981, Elenowitz 1984, Gionfriddo and Krausman 1986, Krausman et al. 1989).
2. Activity of the mountain sheep population in the 3.2 km^2 enclosure was similar to activity of mountain sheep documented by Wilson (1968), Golden and Ohmart (1976), Chilelli and Krausman (1981), Krausman et al. (1985b), and McCutchen (1984).
3. There were acute changes in behavior of mountain sheep as F-16 aircraft flew over the enclosure. When sheep were alerted they often ran, but <10 m before resuming normal activities. Sheep did not move from 1 noise zone to another in response to F-16 overflights.
4. There were acute changes in heart rate as F-16 aircraft flew over the enclosure. When heart rate changed it returned to normal in <3 minutes 96% of the time. Most alterations lasted <1 minute.
5. Our results are similar to those reported by Krausman et al. (1992) and Workman et al. (1992): F-16 aircraft flying over mountain sheep did not create alterations in behavior or increases in heart rate that were detrimental to the population.

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APPENDIX A

SITE NOISE CALIBRATION FOR THE DESERT BIGHORN SHEEP STUDY

Acentech Incorporated

Acoustical & Environmental Technologies

Report No. 38
Project No. 609102

SITE NOISE CALIBRATION FOR THE DESERT BIGHORN SHEEP STUDY

Ramon E. Nugent
David S. Barber

May 1990

Submitted to:

University of Arizona
Biological Sciences East
Room 210
Tucson, Arizona 85721

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* Page no. revised for this report.

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FOREWORD

This report was prepared under contract with the University of Arizona in support of the Noise and Sonic Boom Technology program.

ACKNOWLEDGMENTS

The site calibration for the desert bighorn sheep study was performed under the direction of Ramon E. Nugent of Acentech Incorporated. The authors would like to acknowledge the contribution of the following people for their effort in performing the site calibration:

The Noise and Sonic Boom Impact Technology (NSBIT) program conducted by the United States Air Force Command, Human Services Division, is under the direction of Major Robert Kull, Jr. The project coordination was performed by B. Andrew Kugler, who directs BBN Systems and Technologies' effort for the NSBIT program.

Monitor site coordinates were supplied by University of Arizona staff and students under the direction of Professor Paul R. Krausman. Overflights were coordinated through Captain Bill Woodworth, 57 FWW, United States Air Force, by Major Michael M. Thompson. The coordination with the Desert National Wildlife Range was provided by Bruce Zeller of the U.S. Fish and Wildlife Service.

Special thanks go to the field team members who assisted the authors: Major Robert Kull, Jr., Major Michael Thompson, B. Andrew Kugler, Paul Chavez, Professor Paul R. Krausman, Bruce Zeller, and Dr. Mark Wallace.

EXECUTIVE SUMMARY

This report summarizes the acoustic field calibration efforts of a site located in the Desert National Wildlife Range, Nevada. This work was conducted in support of bighorn sheep behavioral studies designed to develop an understanding of the effects of aircraft noise on animals. The calibration of the site will permit researchers to establish the noise exposure of the bighorn sheep while observing their reactions to aircraft overflights.

The site was calibrated for various noise parameters due to two types of military jet flyovers. The report provides noise level cells for the site in terms of maximum noise level, SEL, L_{eq}, and onset times.

1 INTRODUCTION

This report presents the results of a site noise calibration study performed on an approximately 3 sq km test site located in the East Pahranagat Range of the Desert National Wildlife Range, 90 miles northeast of Las Vegas, Nevada.

The objective of the study was to obtain sufficient noise level data from military jet aircraft flyovers in order to subdivide the test site into noise level cells. This information would later be used to study the effects of low-level aircraft flyover noise on desert bighorn sheep. Approximately twelve animals would be confined in an enclosure encompassing this site and studied over a two-year period.

The field noise measurement procedures and data analyses are described herein and the results are presented on topographical maps in 5 dB noise cells.

2 INSTRUMENTATION

In order to accumulate as much data as possible during a limited test period, 17 noise monitors and 4 tape recorders were employed. The noise monitors included 2 Digital Acoustics DA 607s, 4 Larson-Davis Model 700s, and 11 Larson-Davis Model 870s. Four two-channel Nagra IV-SJ tape recorders were used. This provided a possible 50 recording locations during two days with one day at each location. The recording devices were connected to microphones on tripods. The systems were field calibrated and the microphones were protected with windscreens. The automatic recording units were set to measure events which exceeded 70 dBA.

3 FIELD WORK

The site is located in the East Pahranagat Range of the Desert National Wildlife Range, 90 miles northeast of Las Vegas, Nevada. It encompasses the southern 8000 ft of the East Pahranagat Range and is approximately 5600 ft wide at the center. The site rises abruptly from an elevation of approximately 3800 ft along the south and east edges of the enclosure to an elevation of 4500 to 4687 ft along the ridge running north south at the center of the enclosure. The talus slopes extend from the bottom to the top and are covered with scree and desert plants growing amongst the rubble.

During the first week of December 1989, a team of eight scientists, four from Acentech Incorporated, two from the University of Arizona, and two from the U.S. Air Force traveled to the site to perform noise measurements of low-level aircraft flyovers. One individual from the local U.S. Fish and Wildlife Service also assisted. Arrangements had been made with the 57th FWW of Nellis AFB to provide F-16 and A-10 overflights during the mornings of 4 and 5 January 1990. On 3 January 1990, 17 environmental noise monitors were deployed on the site by four 2-men teams. The monitors were placed, calibrated, and turned on to record noise events.

On the morning of 4 January 1990, 8 additional measurement locations were set up and connected to the 4 two-channel analog tape recorders. The tapes were field calibrated and windscreens were placed on the microphones. Following the aircraft flyovers, the tape recorders and noise monitor data were collected and the monitors were relocated and calibrated in preparation for the next day's flyovers. The following morning, the tape recorders were redeployed and made ready to collect additional data. After the flyovers, the recorders and monitors were collected and the data retrieved.

Figure 1 presents the noise monitor locations. Exhibits 1 through 7 in Appendix A present cross sections of the mountain corresponding to the monitor locations shown in Fig. 1.

The F-16 and A-10 flyovers were provided by the 57th FWW at Nellis AFB. The aircraft were scheduled to fly over the site near the crest of the ridge at an elevation of 4800 ft and intersecting the following sets of coordinates:

Latitude	Longitude
37°15'0"	115°9'27"
37°7'30"	115°8'33"

The aircraft were to maintain normal operating (cruise) speed and a constant elevation during the flyovers. During the first day of flyovers there was very little adherence to the flight directions and the aircraft flew over the area in haphazard flight paths. On the second day most of the overflights were closer to being on course. The A-10 pilots flew at 4900 Mean Sea Level (MSL) elevation and 280 indicated air speeds (88-90% power setting), while the F-16 pilots flew 300 ft above Average Ground Level (AGL) and 480 ground speed (90% power setting). In addition, aircraft approached from both the north and south during the flyovers.

4 ANALYSIS

The three types of noise monitors used automatically sample the data and compute the maximum noise level (L_{max}), the energy equivalent levels of the event (L_{eq}), and sound exposure level (SEL). The analog tape recorded data were later analyzed by a Larson-Davis 870 noise monitor in the laboratory to supply similar information. Only data from those flyovers which were judged by observers to be within ±200 ft of the prescribed flight path were used in the analyses. None of the flights during the first day met this criterion. Data from 8 F-16 and 6 A-10 flyovers recorded at 18 monitor locations during the second day were used. Data used in the analyses are tabulated in Appendix B.

It is evident from the cross sections in Appendix A that at some monitor locations the aircraft were partially shielded from view by the terrain. However, the scatter in noise data due to deviations in flight conditions did not warrant further investigation of this effect.

5 RESULTS

The maximum noise levels measured for the F-16 and A-10 flyovers are presented in Fig. 2. Figures 3 and 4 present the L_{eq} and SEL values for the same flyovers.

Considering only those flyovers which were within ±200 ft of the prescribed flight path, the maximum noise levels at one location varied as much as 16 dB for the F-16 and 13 dB for the A-10. This reflects the range of repeatability of the aircraft flight conditions including possible variation in flight path, flight direction, and aircraft operating conditions.

The results of the regression analysis, based upon Log_{10} of the slant distance, are presented in Table 1. The correlation coefficient, r-squared, is a measure of how well the curve fits the data points, where 1 is a perfect fit to the data points. The equations in Table 1 are statistically highly reliable based on a Student's *t*-test. The standard error of 'y' on $\text{Log}_{10}(r)$ represents one standard deviation of the data. The resulting equations are plotted on Figs. 2, 3, and 4. Aircraft noise measured in units of maximum A-level show reliable relationships for both the A-10s ($r_{98} = .81$, $p < .01$) and the F-16s ($r_{137} = .77$, $p < .01$) as a function of radial distance.

A reliable relationship was also found between aircraft noise measured in units of SEL and radial distance for both the A-10s ($r_{98} = .78$, $p < .01$) and F-16s ($r_{137} = .76$, $p < .01$).

Similarly, statistical significance was obtained when using noise measurements expressed in units of L_{eq} for both A-10s and F-16s ($r_{98} = .81$, $p < .01$; and $r_{137} = .77$, $p < .01$, respectively).

The high level of significance indicates that future noise exposure of the area from aircraft flyovers in accordance with similar flight conditions would yield comparable results.

Figures 5 and 6 present the L_{max} noise contours in 5 dB increments superimposed upon a topographic map of the site for the A-10 and F-16 aircraft, respectively. These contour areas are based upon the regression formulas presented in Table 1. Table 2 presents the correlation of the L_{max} contour areas in Figs. 5 and 6 with corresponding SEL and L_{eq} values.

There is some speculation that the onset time of the noise event (how sudden the noise increases) may enter into the way noise effects wild animals. Appendix C contains figures showing typical rise in noise level with time during F-16 and A-10 flyovers. Under the flight path, the A-10 rise time is approximately 8.5 dB/sec while the F-16 is more abrupt having an onset time of 25 to 33 dB/sec. The

F-16s are also approximately 10 dB louder than the A-10s. Table 3 correlates the range of onset times that may be expected in each of the noise contour areas shown in Figs. 5 and 6.

6 CONCLUSIONS

The capability of modern noise monitoring equipment enables a site to be acoustically calibrated. The tolerance of the calibration will depend upon the repeatability of the aircraft to maintain a flight path and a set of operating conditions. Pilots should be instructed to (1) fly at 4800 MSL above the site, (2) maintain power settings of 90%, (3) maintain flight course within ±200 ft of the prescribed flight path, and (4) approach from the same direction. The adherence to these flight conditions should be closely monitored and procedures developed which can reduce deviation from the overflight program.

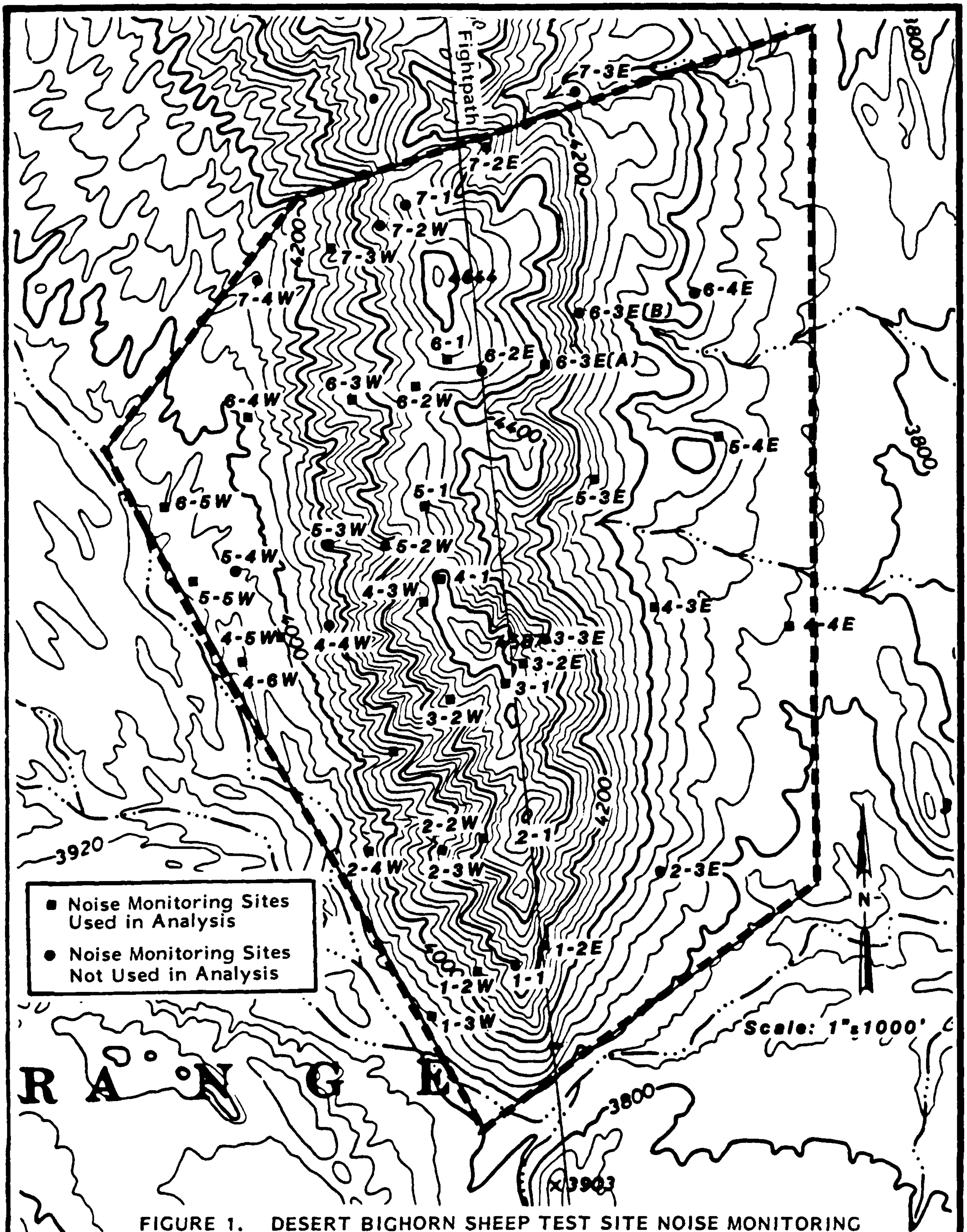


FIGURE 1. DESERT BIGHORN SHEEP TEST SITE NOISE MONITORING LOCATIONS

FIGURE 2.

SUMMARY OF Lmax DATA

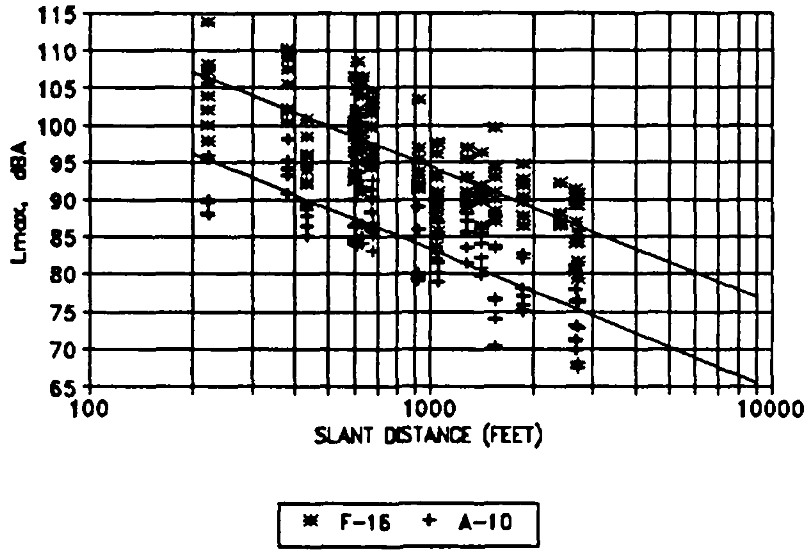


FIGURE 3.

SUMMARY OF Leq DATA

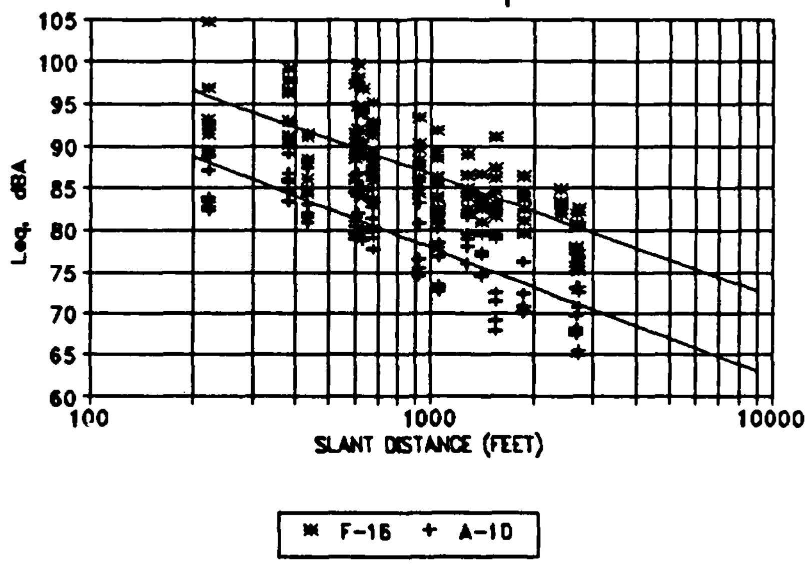
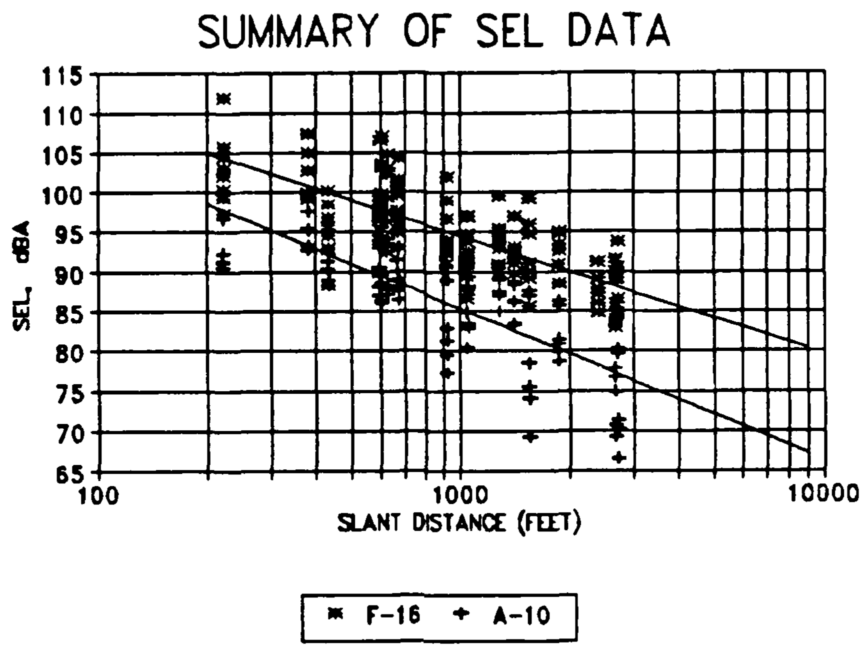


FIGURE 4.


SUMMARY OF SEL DATA
115
110
105
100
95
90
85
80
75
70
65
SEL, dBA
100
1000
10000
SLANT DISTANCE (FEET)
F-16
A-10

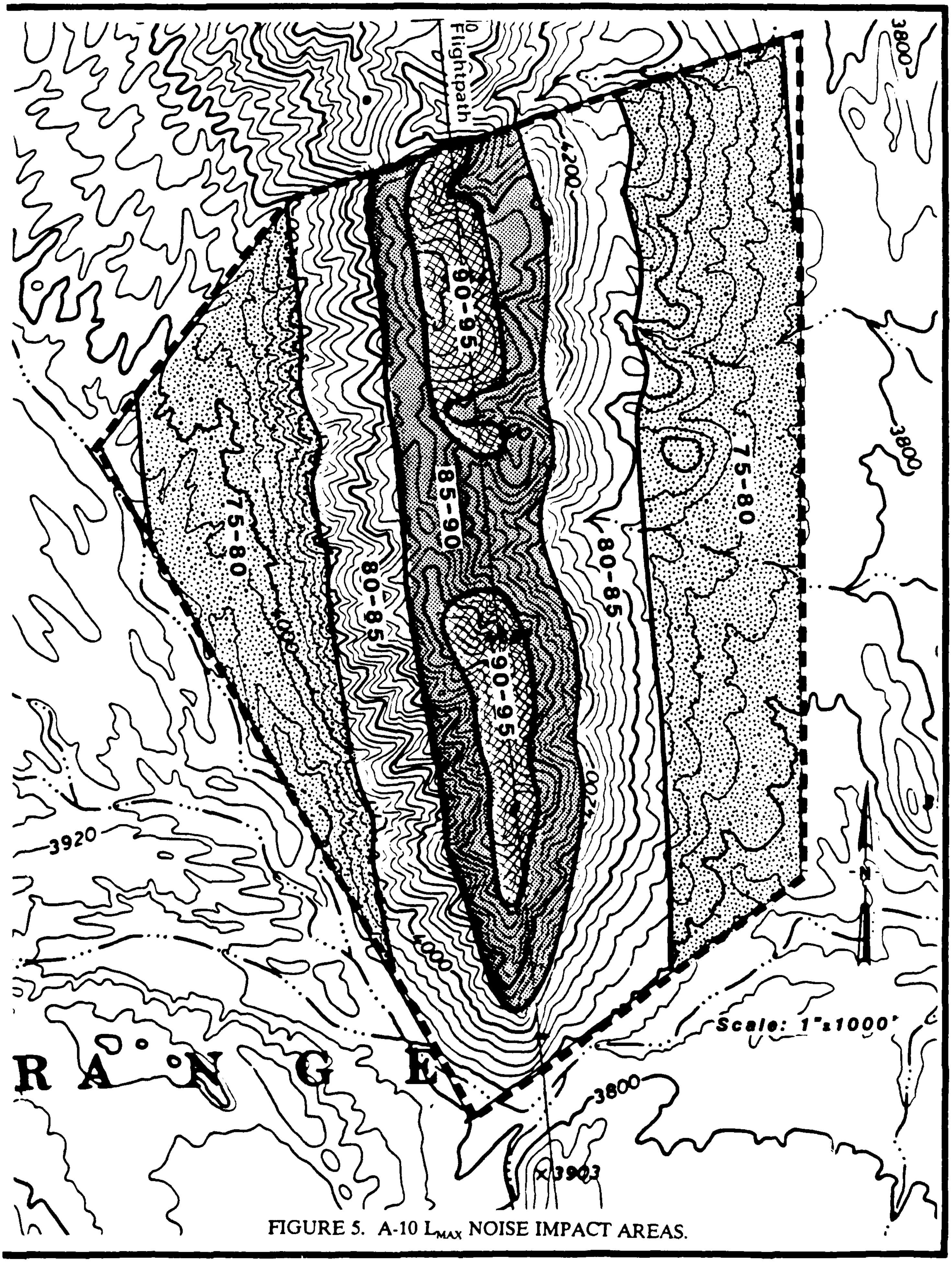


FIGURE 5. A-10 L_{MAX} NOISE IMPACT AREAS.

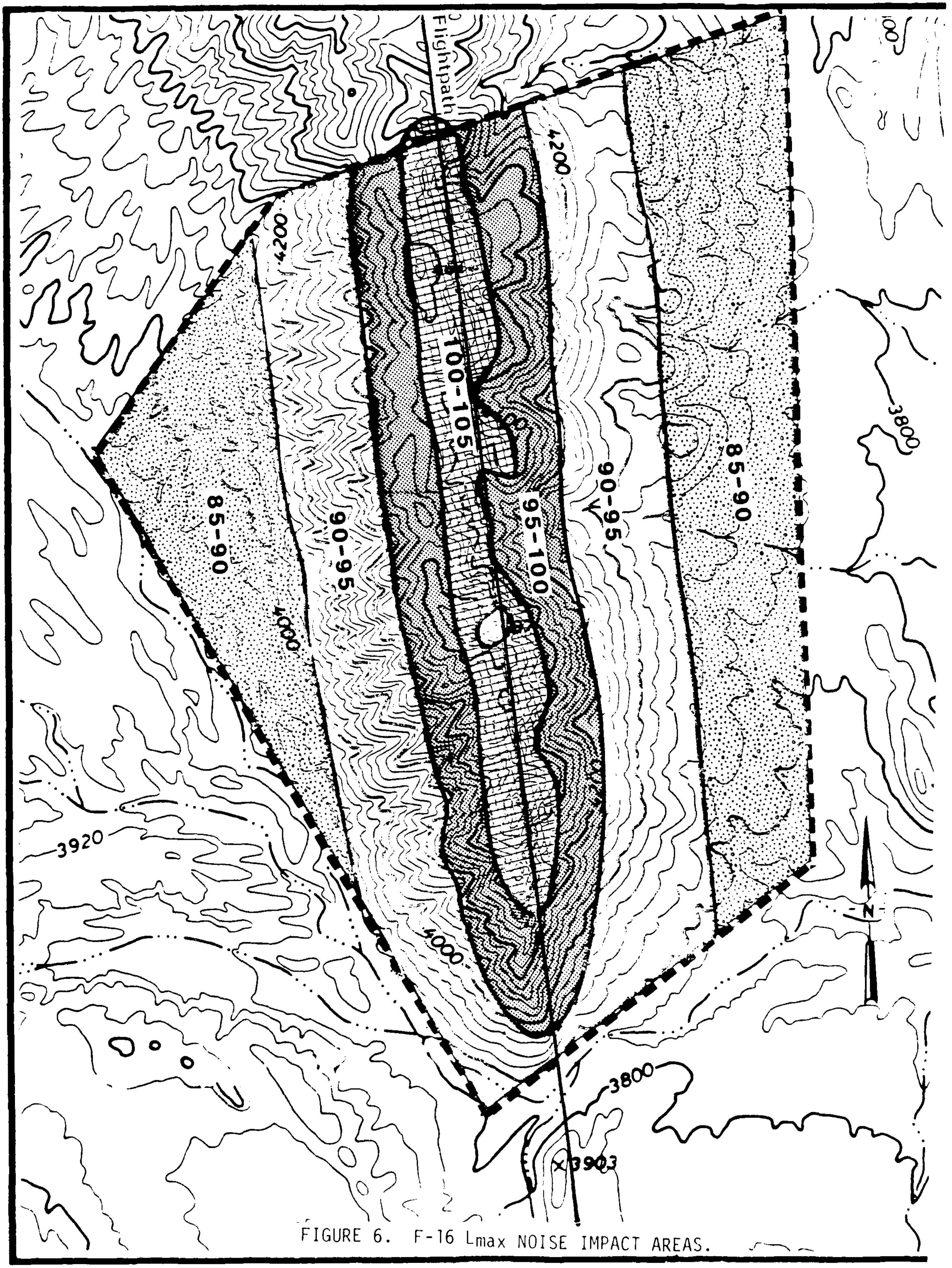


FIGURE 6. F-16 Lmax NOISE IMPACT AREAS.

TABLE 1. MEAN REGRESSION ANALYSIS RESULTS

	F-16			A-10		
	SEL	L_{eq}	L_{max}	SEL	L_{eq}	L_{max}
Equation	-14.9 Log(r) + 139.2	-14.4 Log(r) + 129.7	-18.4 Log(r) + 149.4	-19 Log(r) + 142.4	-15.5 Log(r) + 124.5	-18.6 Log(r) + 138.9
$r_{x,y}$	0.75**	0.77**	0.77**	0.78**	0.81**	0.81**
r Squared	0.57	0.59	0.60	0.61	0.65	0.65
Standard Error of 'y' on Log(r)	3.81	3.56	4.46	4.44	3.28	4.91
No. of Observations	139			100		
Degrees of Freedom	137			98		

** p<0.01

TABLE 2. NOISE CONTOUR AREA CORRELATION*

Type of Aircraft	L_{max} Contour Area	L_{eq}	SEL
A-10	90-95	83-87	92-97
"	85-90	79-83	87-92
"	80-85	75-79	82-87
"	75-80	71-75	77-82
F-16	105-110	95-99	103-107
"	100-105	91-95	99-103
"	95-100	87-91	95-99
"	90-95	83-87	91-95
"	85-90	79-83	87-91

TABLE 3. ONSET TIME CORRELATION*

Type of Aircraft	L_{max} Contour Area	Onset Time dB/sec
A-10	90-95	6.3-8.6
"	85-90	4.3-6.3
"	80-85	3.0-4.3
"	75-80	2.1-3.0
F-16	105-110	22.2-28.3
"	100-105	14.5-22.2
"	95-100	10.8-14.5
"	90-95	7.3-10.8
"	85-90	5.2-7.3

* The L_{eq}, SEL, and onset time ranges correspond to the L_{max} contour areas shown in Figs. 5 and 6.

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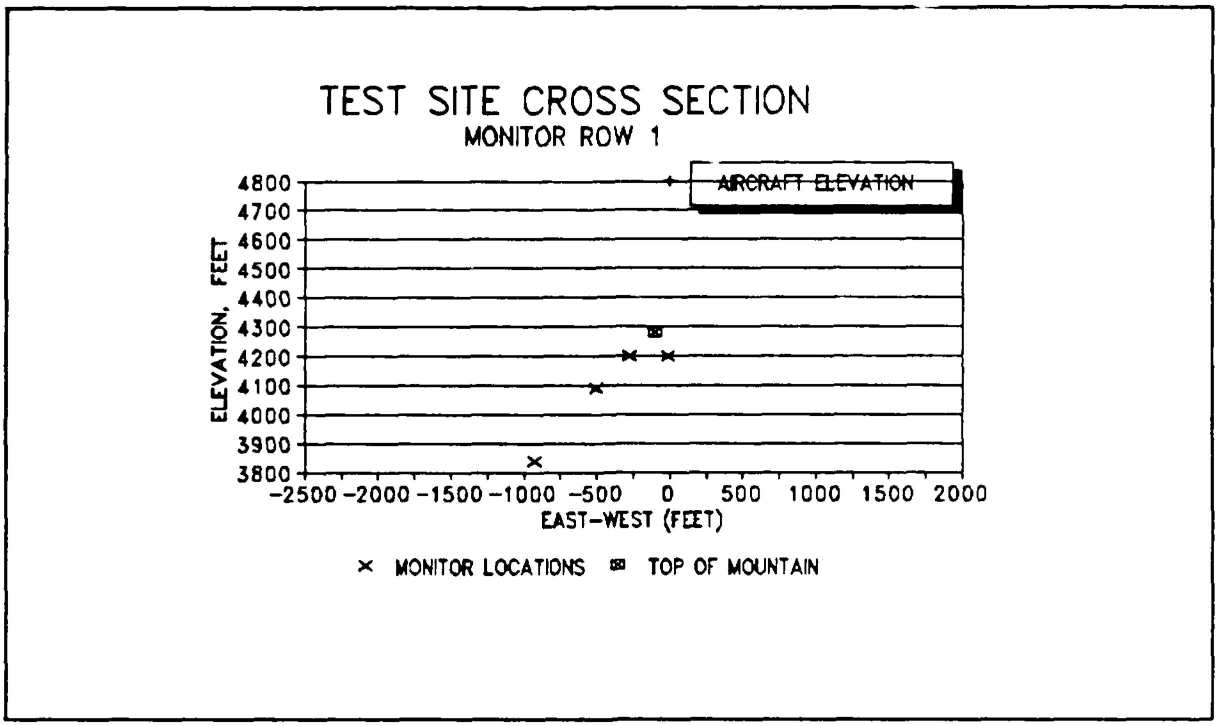
APPENDIX A

TEST SITE CROSS SECTIONS



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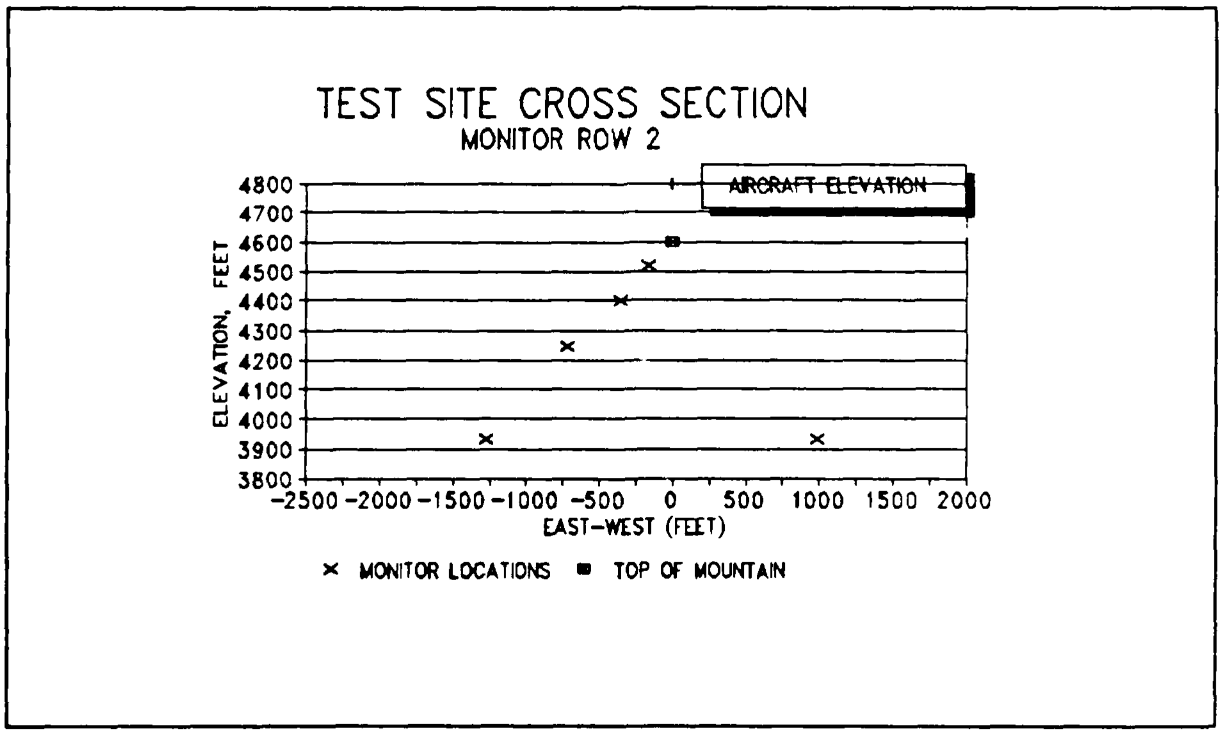

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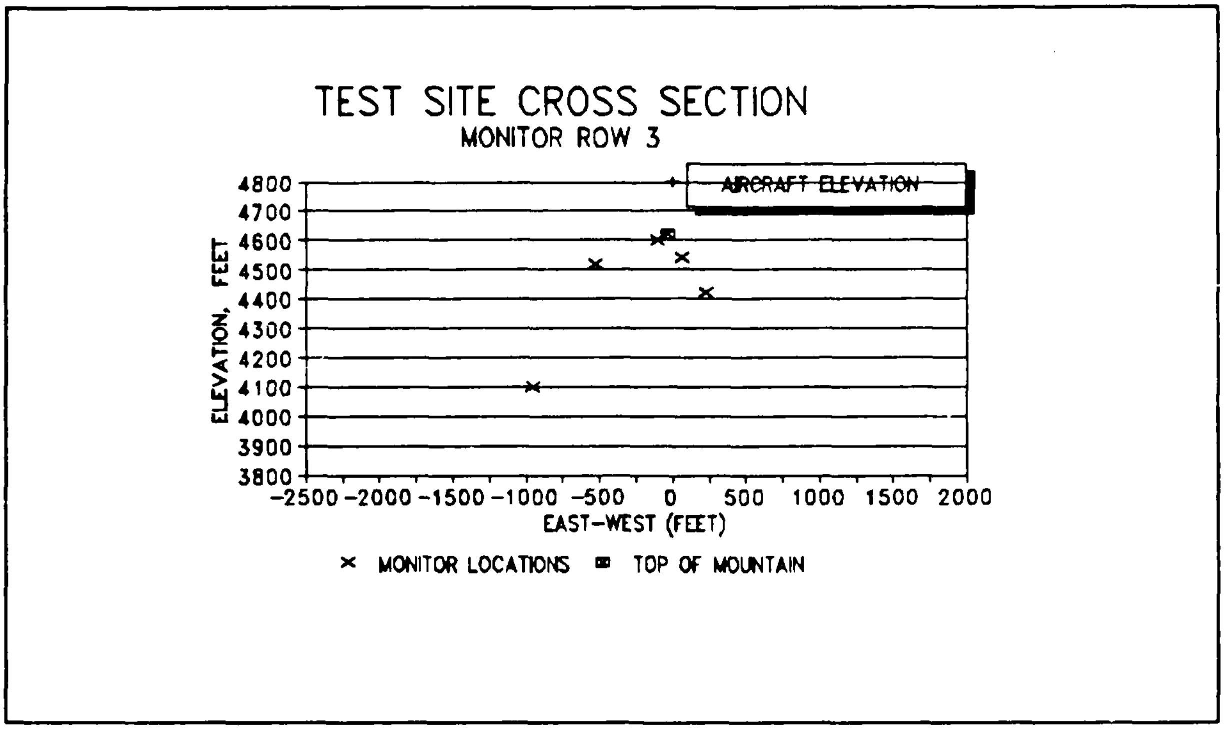

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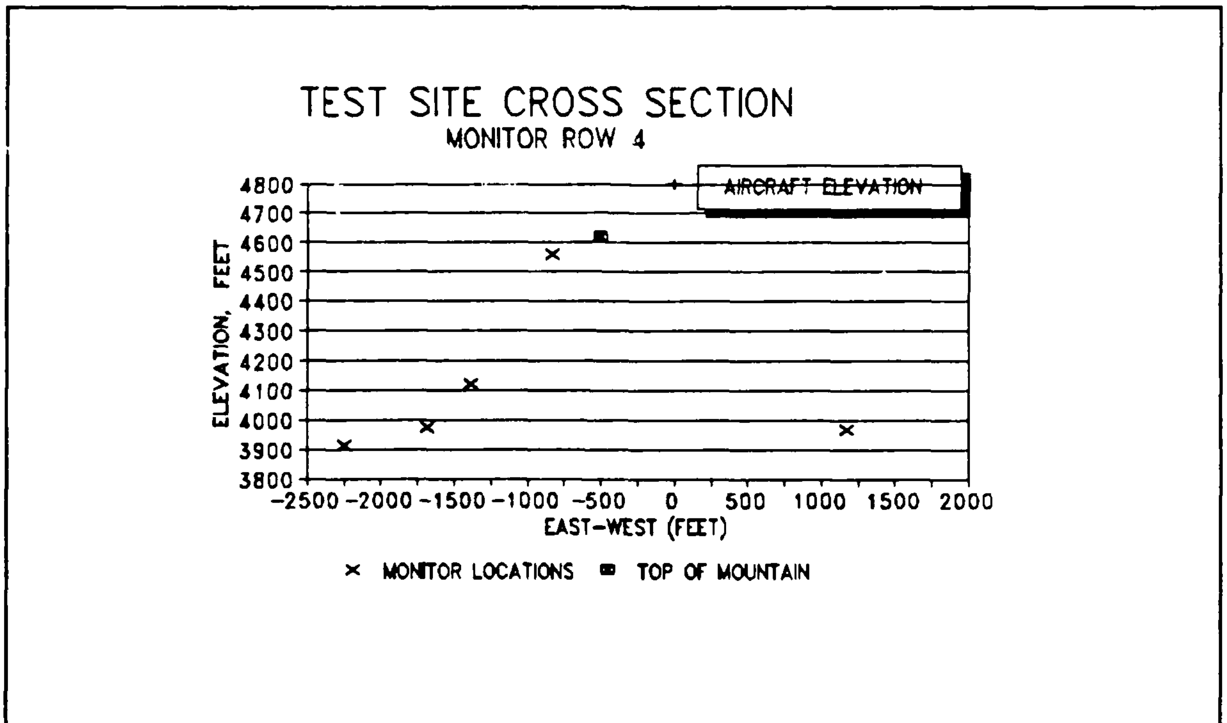

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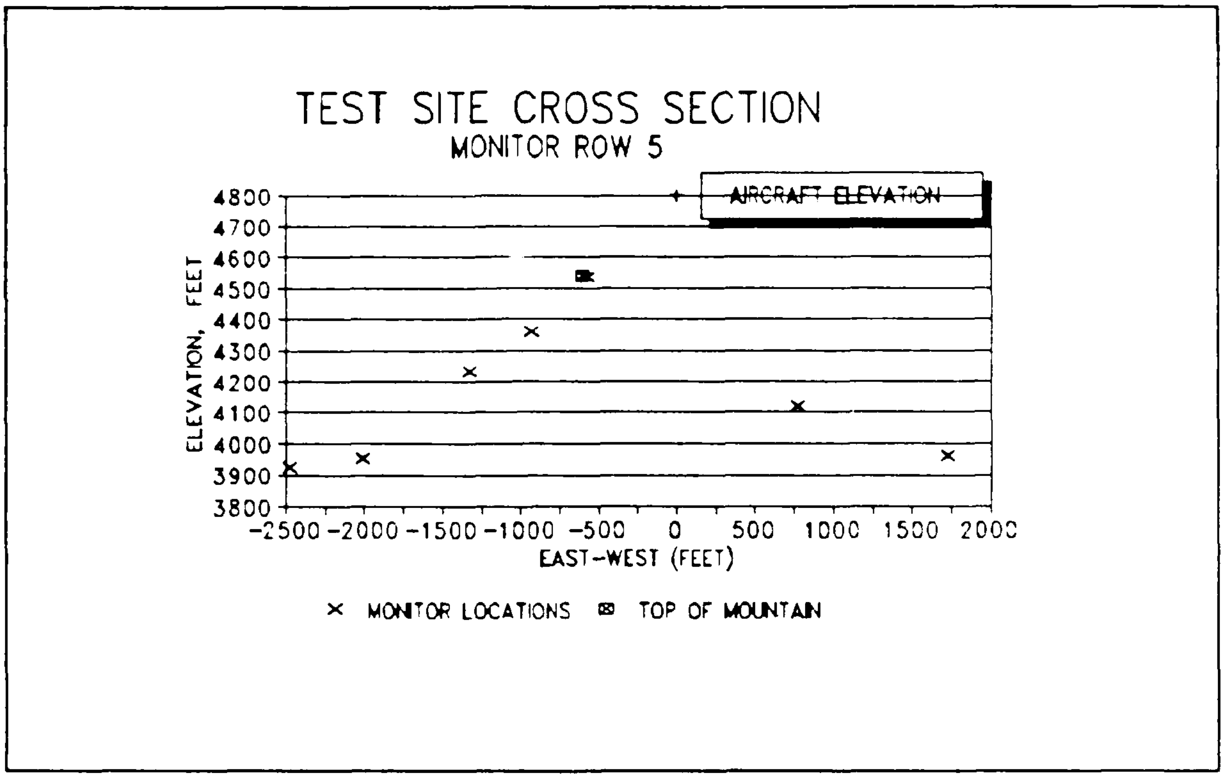

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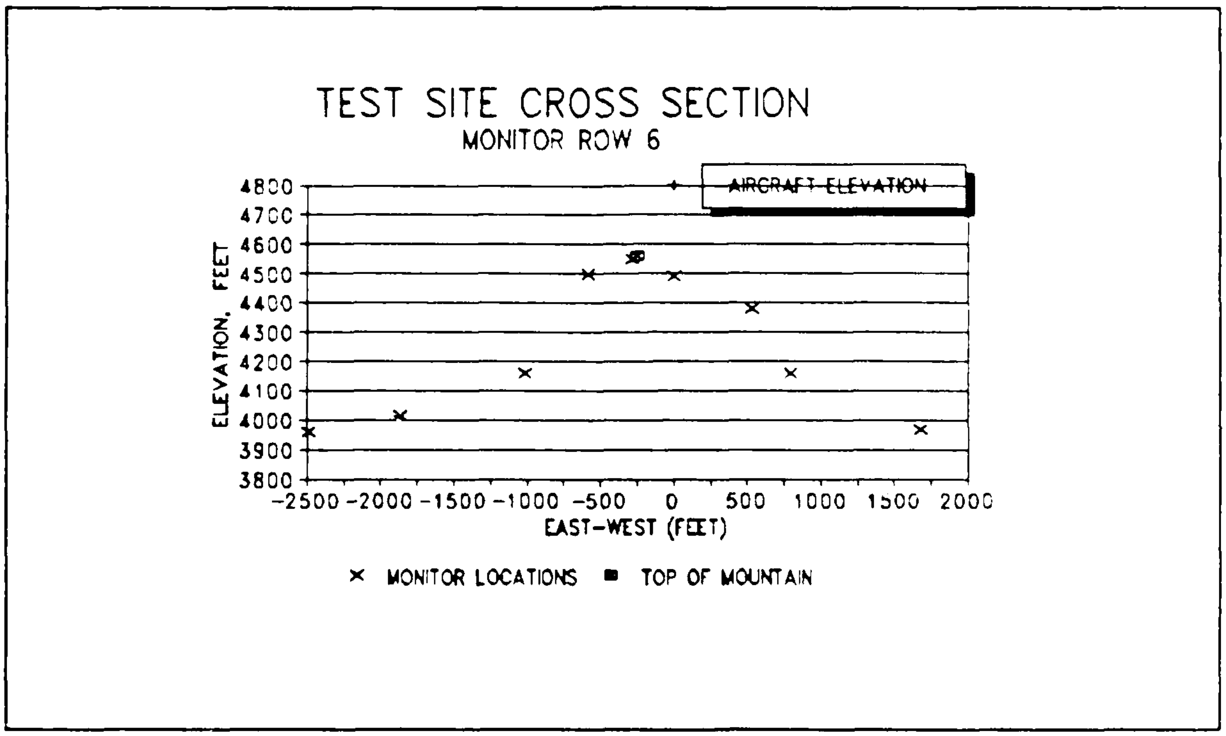

EXHIBIT A-6.

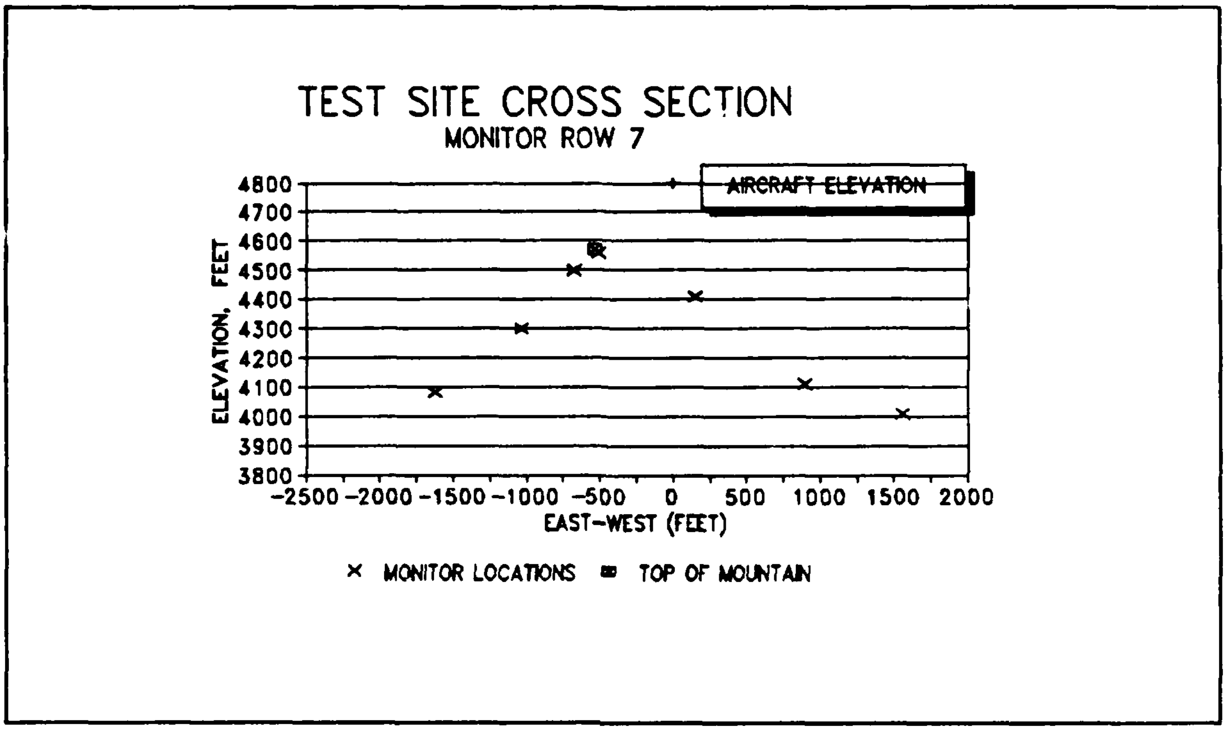
TEST SITE CROSS SECTION
MONITOR ROW 7
AIRCRAFT ELEVATION
ELEVATION, FEET
4800
4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
-2500 -2000 -1500 -1000 -500 0 500 1000 1500 2000
EAST-WEST (FEET)
× MONITOR LOCATIONS
TOP OF MOUNTAIN

EXHIBIT A-7.

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APPENDIX B

NOISE DATA USED IN THE ANALYSES

Nevada Bighorn Sheep Sound Monitoring Data
Acentech Project No. 609102

Point	COORDINATES - FEET East	North	Elev.	Radial Distance	F-16 Leq dBA	A-10 Leq dBA	F-16 SEL dBA	A-10 SEL dBA	F-16 Lmax dBA	A-10 Lmax dBA
Day 2 data										
1-2 E	2180553	13497968	4200	600	89.5	79.5	97.5	88	98.5	84.5
1-2 E				600	88.5	81	97	90	100	86.5
1-2 E				600	86	84.5	90	93	92.5	90
1-2 E				600	86		94		93.5	
1-2 E				600	90.5	79	98.5	87	99	84
1-2 E				600	88.5	80.5	96.5	89.5	96.5	84.5
1-2 E				600	97.5		106.5		106.5	
1-2 E				600	91.5	81.5	99.5	90.5	100.5	86.5
2-3 E	2181438	13498526	3930	1285	85	76	94.5	85	93	81.5
2-3 E				1285	84	79	93.5	87.5	93	85.5
2-3 E				1285	86.5	81.5	95.5	91	95.5	87
2-3 E				1285	84	79.5	93	89	91	85.5
2-3 E				1285	89		99.5		97	
2-3 E				1285	85	82	94	91	93	88
2-3 E				1285	84	78	90	87	90	83.5
2-3 E				1285	82.5		91		89	
2-3 W	2179732	13498690	4245	919	85.6		92.3		91.4	
2-3 W				919	93.4	83.2	102	90.7	103.5	88.9
2-3 W				919	87.5	76.6	93.9	82.8	93.2	79.4
2-3 W				919	84.3	74.5	91	77.2	91.7	79
2-3 W				919	86.2	74.5	92.6	81.3	92.1	79.8
2-3 W				919	88.2	75.5	93.7	79.5	93.8	80.2
2-3 W				919	90.3		99		95.4	
2-3 W				919	89.6	80.7	96.7	88.9	96.9	85.9
2-4 W	2179175	13498690	3930	1554	87.3		96		93	
2-4 W				1554	83.2	71.5	90.1	75.5	88.4	74
2-4 W				1554	87.3	79	94.7	87	94.2	83.6
2-4 W				1554	86.2	69.2	89.9	74	90	76.4
2-4 W				1554	91.1	79.4	99.2	87.6	99.7	83.4
2-4 W				1554	82.5	67.9	85.5	69.2	87	70.3
2-4 W				1554	84.6	72.5	91.1	78.5	91	76.7
2-4 W				1554	81.6		89.1		87.5	
3-1	2180225	13500068	4600	222	96.9	82.3	104.5	90.5	107.3	88
3-1				222	92.5		100.3		102.1	
3-1				222	89.5	83.9	99.3	92.3	100.1	90
3-1				222	91.5	87.1	97.3	96.8	97.9	95.5
3-1				222	93.2	83.4	103	91.3	105.8	89.6
3-1				222	104.7		111.9		113.8	
3-1				222	96.9	88.7	105.7	96.7	108.2	95.9
3-1				222	92.6	82.8	102.1	91.1	104	87.9
3-2 W	2179798	13499904	4520	607	92	79.5	99.9	86.3	101.1	83.9
3-2 W				607	89.6	79.9	98	88.6	98.2	84.8
3-2 W				607	89.1		97.5		97.6	
3-2 W				607	99.8		107.1		108.5	
3-2 W				607	98.2	86.8	103.6	95.7	106.5	93.8
3-2 W				607	89.7	79.4	99	86	102.1	84.7
3-2 W				607	94.8	84.9	103.2	94.4	104.9	92.5
3-2 W				607	84.6	82	93.9	89.5	95.1	86.8
4-3 E	2181406	13500659	3970	1410	83.9	79.4	93.1	88.7	91.6	85.3
4-3 E				1410	82.4	77	91.1	86.2	89.7	82.2
4-3 E				1410	83.4	79.4	92.7	88.4	90	86
4-3 E				1410	83.3	74.6	92.4	83.3	90.7	80.7
4-3 E				1410	80.9		89.7		86.5	
4-3 E				1410	83.6	77.4	91.9	86.3	91.9	84
4-3 E				1410	86.6		97		96.3	
4-3 E				1410	82.8	74.4	91.6	83.4	91	79.8
4-4 E	2182488	13500528	3835	2405	81.9		86		86.9	
4-4 E				2405	83.3		89.2		88.1	
4-4 E				2405	82.6		84.8		86.4	
4-4 E				2405						
4-4 E				2405	84.9		91.2		92.2	
4-4 E				2405	83.5		87.9		87	
4-4 E				2405	83.4		87.2		86.6	
5-1	2179601	13501446	4535	630	93.9	85.2	102.2	93.6	104	91.7
5-1				630	90.6	79.1	99.3	87.1	100.1	85

Point	COORDINATES - FEET East	North	Elev.	Radial Distance	F-16 Leq dBA	A-10 Leq dBA	F-16 SEL dBA	A-10 SEL dBA	F-16 Lmax dBA	A-10 Lmax dBA
5-1				630	94.6		104.8		105.9	
5-1				630	88.9	78.8	96.4	87.1	96.7	85
5-1				630	89.3		97.6		99.1	
5-1				630	88.8	80.3	97.3	88.2	97.9	86.7
5-1				630	96.8	84.8	103.1	94.1	106.6	91.5
5-1				630	84.1	79.7	92.4	87.8	91.1	84.1
5-2 W	2179240	13501151	4360	1057	81.2	73.1	91.1	83.4	89.1	81.7
5-2 W				1057		78.5		89.4		86.9
5-2 W				1057	80.3		92.5		91.1	
5-2 W				1057	82.5	72.9	92.4	83.1	90.5	80
5-2 W				1057	78	73.4	87.7	83	85.7	81.4
5-2 W				1057	82.1	72.6	91.3	82.9	89.8	78.9
5-2 W				1057	85.4	76.9	96.9	88.1	97.5	85.6
5-3 E	2180946	13501643	4120	1040	89.2	80.1	93.8		93.4	
5-3 E				1040	83.7	80.7	90	85	87.3	82.9
5-3 E				1040	91.9		96.9		97.6	
5-3 E				1040	84	81.7	89.5	84.9	88.8	85
5-3 E				1040	88.4	84.2	94.7	90.7	96.1	88.3
5-3 E				1040	86.1		91.9	80.4	93	82.1
5-3 E				1040	81.5		86.6		83.6	
5-3 E				1040	86.3	81.9	91.9	88.1	90.5	84.8
5-5 W	2177698	13500856	3925	2673	80.8	73.1	90	77.8	90.7	77.9
5-5 W				2673	75.7		83.6		80.4	
5-5 W				2673	78	69.8	85.9	70.7	84.1	71
5-5 W				2673	80.8	73.2	89	74.9	86.9	76.3
5-5 W				2673	80.6	67.5	89.2	69.2	91.3	69.9
5-5 W				2673	81.9		91.6		89.1	
5-5 W				2673	77.8	67.9	82.9	69.2	84.1	71.2
5-5 W				2673	75.7	68.3	83.9	76.6	80.6	73.2
6-1	2179765	13502595	4550	380	99.14	86.04	107.24	95.44	110.04	95.24
6-1				380	96.64	89.14	104.94	97.64	109.04	98.14
6-1				380	97.84		107.44		110.34	
6-1				380	93.04	85.74	102.64	95.14	105.54	94.24
6-1				380	90.24		99.14		100.44	
6-1				380	91.04	86.74	99.64	95.24	101.94	94.14
6-1				380	96.34	84.54	105.04	93.34	107.54	93.24
6-1				380	91.14	83.44	99.94	92.74	102.24	90.84
6-2 W	2179470	13502365	4500	675	87.8		95.9		96.3	
6-2 W				675	92.1	83.9	101.1	93.1	102.5	92.6
6-2 W				675	92.7	83.5	100.9	92.9	103.7	90.4
6-2 W				675	92.9	79.1	101.6	87.6	103.1	85.8
6-2 W				675	89.1	79.9	96.9	89	96.7	86.7
6-2 W				675	86.7	77.8	95.9	86.4	96.2	83.1
6-2 W				675	95.2		104.2		104.7	
6-2 W				675	85.9	80.5	95	88	94.9	85.1
6-3 Ea	2180585	13502562	4380	673	91.3	82.8	99.5	91.5	100.1	88.3
6-3 Ea				673	89.3	84.9	97.8	93	97.2	91.4
6-3 Ea				673	88.6	80.1	97.1	88.9	95.7	85.9
6-3 Ea				673	87	83.5	95.4	93.2	94.3	89.9
6-3 Ea				673	91.8	86.7	100.7	96.5	99.7	94.8
6-3 Ea				673	91.9	81.4	100.1	89.9	101.5	86.3
6-3 Ea				673	92.8		101.3		102.2	
6-3 Ea				673	86.4		94.8		94.7	
6-4 W	2178190	13502135	4015	1877	81.1	70.1	88.6	78.7	90.3	75.1
6-4 W				1877	79.5	70.3	88.5	79.9	86.4	75.9
6-4 W				1877	84.6		95		94.8	
6-4 W				1877	83.7	76.2	92.6	86.3	91.9	82.1
6-4 W				1877	79.7		88.6		87.7	
6-4 W				1877	82.5	72.3	90.8	81.4	89.7	78
6-4 W				1877	86.4	70.9	94.8	80.8	94.8	77.1
6-4 W				1877	84	76.2	93.4	85.7	92.6	82.6
6-5 W	2177567	13501446	3960	2727	80.3	73.2	89.2	80.3	85.6	76.5
6-5 W				2727	75.2		84.4		79.4	
6-5 W				2727	76.2	70.9	84.9	71.4	81.6	72.7
6-5 W				2727	80.5	72.5	90.6	79.6	89.1	76.2
6-5 W				2727	82.1	65	90.5	66.5	90.6	67.4
6-5 W				2727	77.1	65.5	86.6	70.1	84.2	68.1
6-5 W				2727	82.7		93.8		90.7	
7-2 E	2180060	13504301	4410	433	88.4	83.1	96.8	90.3	96.1	87.7

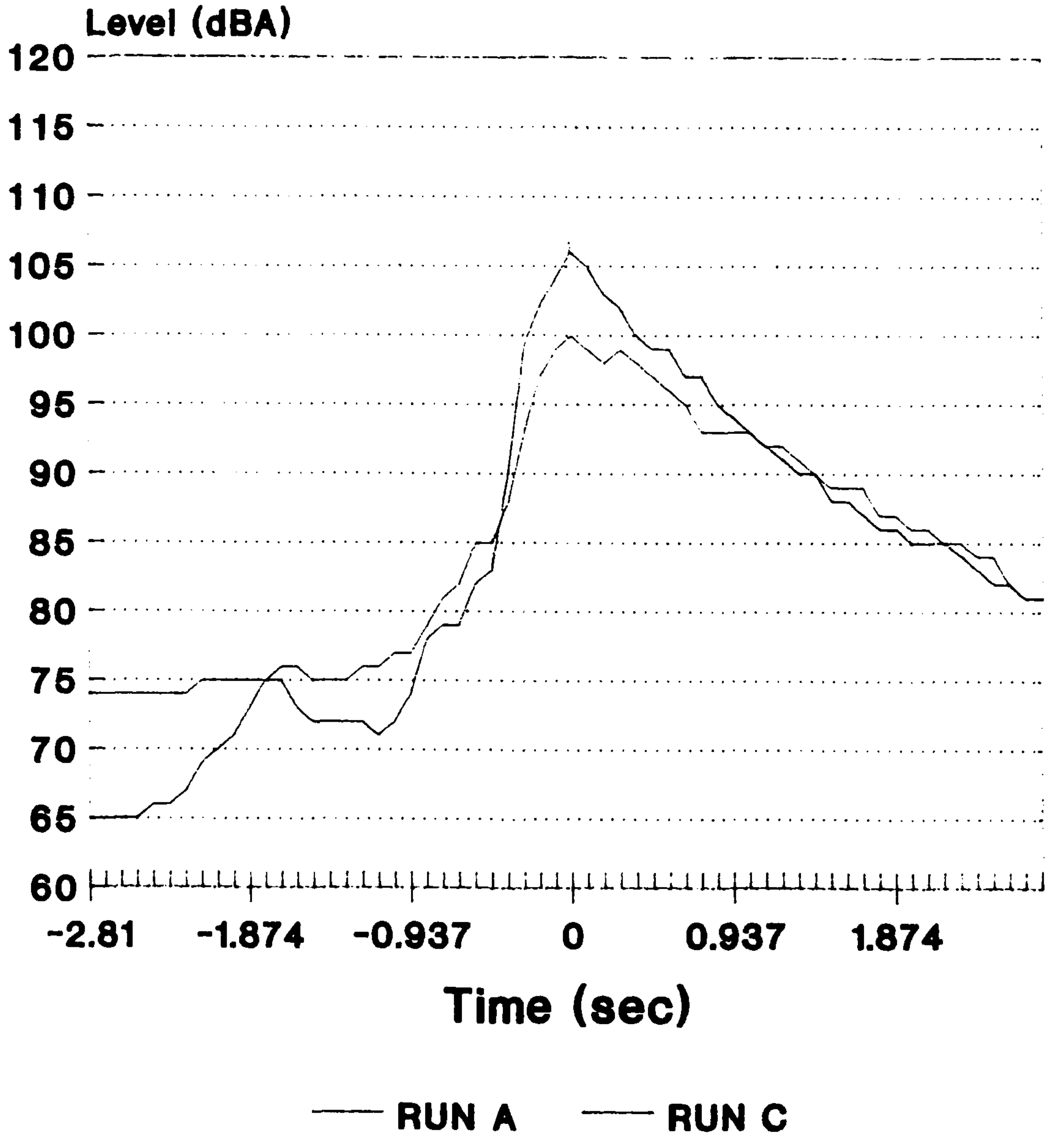
Point	COORDINATES - FEET East	North	Elev.	Radial Distance	F-16 Leq dBA	A-10 Leq dBA	F-16 SEL dBA	A-10 SEL dBA	F-16 Lmax dBA	A-10 Lmax dBA
7-2 E				433	88	81.5	95.8	90.1	95.9	87.8
7-2 E				433	84.7	81	88.4	88.9	89.2	86.4
7-2 E				433	91.6	87.4	100.2	95.4	100.9	94.4
7-2 E				433	84.9		92.9		92.3	
7-2 E				433	86.1	80.9	94.6	88.2	94	85.1
7-2 E				433	84.4	82	93	91.3	92	88.8
7-2 E				433	91.2		98.5		98.5	

ACENTECH INCORPORATED

APPENDIX C

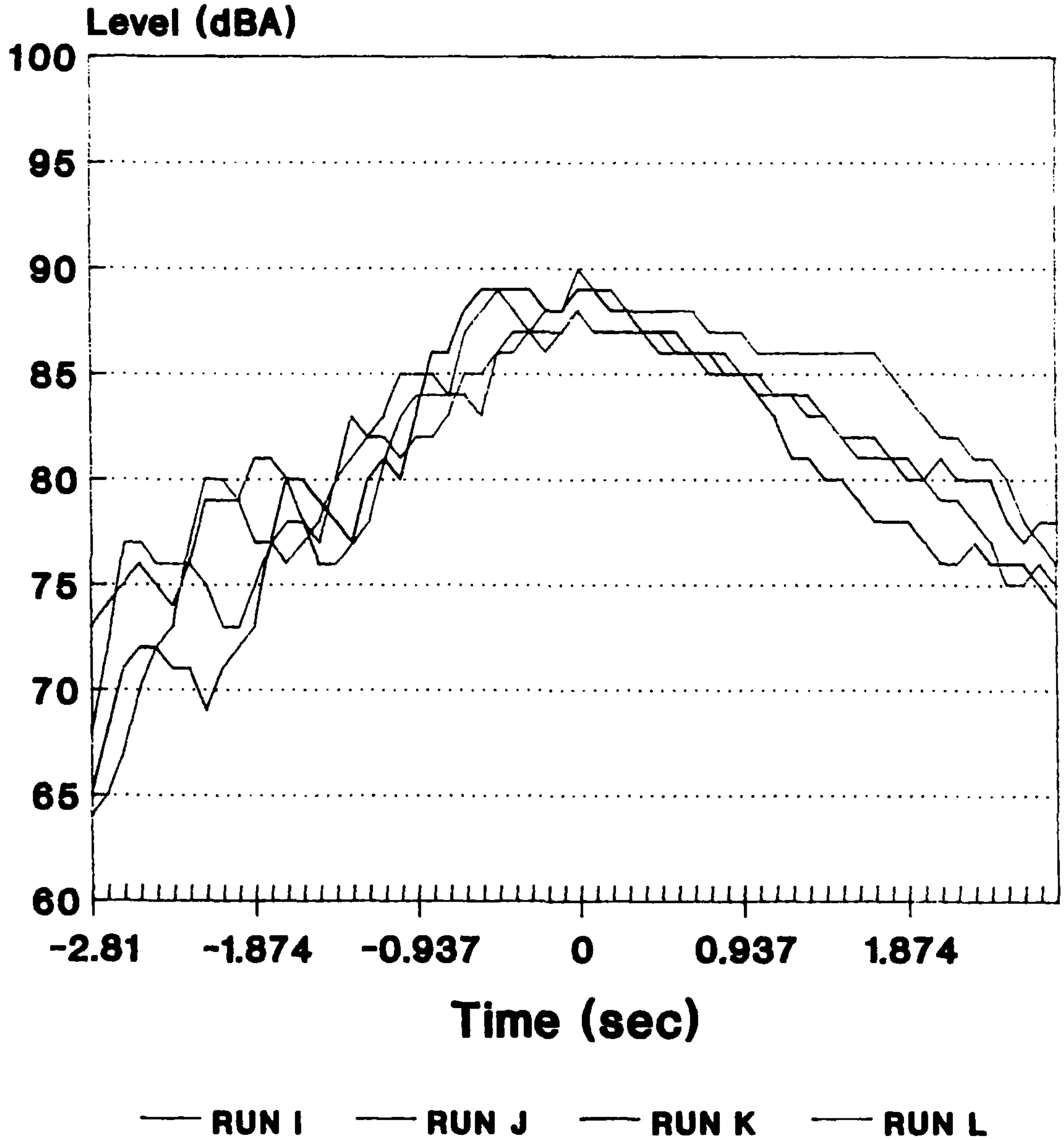
TYPICAL FLYOVER RISE TIME PROFILES

F-16 ON CENTER LINE
LOCATION 3-1



05 January 1990

A-10 ON CENTER LINE
LOCATION 3-1



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APPENDIX B

CHRONOLOGY OF F-16 OVERFLIGHTS OVER AN ENCLOSED POPULATION OF MOUNTAIN SHEEP IN THE DESERT GAME RANGE, NEVADA

APPENDIX B. Chronology of F-16 Overflights Over an Enclosed Population of Mountain Sheep in the Desert Game Range, Nevada.

Dates	Activity
1989	Enclosure construction
Dec 1989 - Jan 1990	Calibration of the sound field produced by overflights in the enclosure.
May 1990 - May 1991	Mountain sheep were placed in the enclosure (1 yearling F, 7 ad F, 1 yearling M, 3 ad M). Data collected on behavior and habitat use.
2 May 1991	Five more sheep were added to the enclosure after being instrumented with heart-rate monitors.
24 May - 27 Jul 1991	Treatment period 1[a].
20 Sep - 20 Nov 1991	Treatment period 2.
4 Feb - 2 Apr 1992	Treatment period 3.
Summer 1992	Enclosure removed.

[a] During treatment periods F-16 aircraft were randomly scheduled to fly over the enclosure during diurnal hours in the middle 4 weeks of each period. During the first week 1 aircraft/day was scheduled to fly over the area. The following 2 weeks ≤7 aircraft/day flew over the enclosure. During the last week 1 aircraft/day was scheduled to fly over the enclosure. Aircraft were not scheduled to fly on weekends.

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